

The Social Startup Game:
Creating an Educational Cybersecurity Game and Collecting Empirical Data

An Honor's Thesis (HONR 499)

by

Kaleb Stumbaugh

Thesis Advisor
Dr. Paul Gestwicki

Ball State University
Muncie, IN

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Abstract

We discuss our methods and justifications for game design decisions. We identify three major learning outcomes that must be met by our game designs. Through a literature review, we create a three-tier taxonomy of games and discover that most education cybersecurity games do not have empirically proven efficacy. We discuss our prototyping process and justify our game design decisions. We test the game with thirteen children in our target age range and identify four major themes: Mixed views on education and career goals, diverse opinions about developers' appearance and interests, impact of background knowledge, and two modes of character driven decisions. These observations support our thesis that type three games would be useful for addressing our design and educational goals. We also identify a need future work to be done in five distinct areas: cybersecurity educational game design, cybersecurity education game validation, the role of narrative in games, asynchronous, asymmetric games in relation to security, and youth perceptions of cybersecurity careers and practices.

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Thank you to Dr. Paul Gestwicki, for his unwavering patience and insight. Your tutelage has defined my computer science education at Ball State, and I am a better academic, computer scientist, and critical thinker because of it.

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Introduction

Dr. Gestwicki and I began working on this project in May of 2015. The project is composed of two major components; the first, an educational video game to teach children in middle and high school about cyber security practices, career paths, and educational opportunities. The second component is a qualitative study that tests the effects of the game and seeks to show whether or not the students learn what we set out to teach from playing the game.

When framing this work, we turn to two themes from the Cybersecurity Education Workshop Final Report (Cybersecurity Education Workshop): Assessment and Recruitment and Retention. The former deals with the development of reliable and valid techniques for measuring subjects' understanding of cybersecurity as well as methods for evaluating educational interventions. The latter deals with the "pipeline" problem, that there are not enough people preparing for and staying in cybersecurity careers to meet the demand.

Introduction into Serious Game Design

Dr. Paul Gestwicki is an Associate Professor of Computer Science whose primary scholarship is in educational game design. I took an Honors colloquium taught by Dr. Gestwicki in the fall of 2014 entitled "Serious Game Design." Our main text for this course was *A Theory of Fun and Game Design* (Koster, 2005) which discussed game design and a theory of fun. We also discussed the role of play within games, utilizing five freedoms afforded by play (Klopfer, Osterweil, Salen, 2009):

1. Freedom to Fail
2. Freedom to Experiment
3. Freedom to fashion identities
4. Freedom of Effort
5. Freedom of Interpretation

During the colloquium, we played many different styles of games as a form of research. I was exposed to many genres I had never experienced and became accustomed to game design jargon. Forced to think critically about gaming systems and their interactions, I realized that gaming systems can be viewed in the same manner as software, where all of the mechanics can be quantified and measured. Like software, a player's interactions with the system and with other users cannot be quantified and so must be qualitatively tested and evaluated. I designed several games themed around the International Space Station, and created several iterations of each game, refining their game play based on user testing data.

In the spring of 2015, Dr. Gestwicki lead an immersive learning project that set out to create a cooperative, multiplayer video game based on the International Space Station using the ideas cultivated during the fall colloquium. Our team paired with Cathy Hamaker and Despi Ross from The Children's Museum of Indianapolis, drawing upon their experience with our target audience and educational game design. Through the use of a Scrum Development methodology, we were able to quickly create teams to deal with specific tasks, from asset production to network coding to user testing (Deemer, Benefield, Larman, Vodde, 2012).

I was involved in many parts of the coding process, including back end structure, networking, and asset integration. I was also highly involved in the user testing process, where I

learned how to interpret player reactions and data; in particular, we had to wade through the data because what children say is not always congruent with what they mean. They may lack the proper words to articulate what they feel, or they may not be aware of how they are affected by something.

We presented this game at the 2015 Butler Undergraduate Research Conference and the 2015 Ball State Student Symposium, which exposed me to academic conferences for the first time. The semester ended with the publication of our game, *Collaboration Station*, to the Google Play Store.

In the fall of 2015, I approached Dr. Gestwicki with the offer to pursue a research fellowship. In the Spring of 2016, he was awarded a grant by the Software and Security Engineering Research Center to create a game to educate on cyber security, and he offered to bring me in on that work. This project evolved into *The Social Startup Game*.

Epistemology

The Cybersecurity Education Workshop Final Report Cybersecurity Education Workshop identified six major research themes for immediate action, in order to address deficiencies in contemporary computer security education practice. The first of these—*Concepts and Conceptual Understanding*—is the topic of our cybersecurity epistemology, particularly as applied to educational games (Gestwicki and Stumbaugh, 2015, a).

We applied this idea of creating an epistemology through a structured literature review that included academic articles, papers on both game design and cybersecurity, computer science education standards, and many different games, both digital and analog. Many of our findings and resulting conclusions are detailed in our paper *Observations in Cybersecurity Education Game Design* (Gestwicki, Stumbaugh, 2015), which is the next section of this paper, and so will not be covered here.

CS 2013 states that cybersecurity practice balance three core ideas: confidentiality, integrity, and accessibility.

- Confidentiality — Private information should only be given to reputable sources, and should be kept safe by those sources. Confidentiality is improved through training and education of users and employees. Susceptible to social engineering attempts, such as phishing attempts.
- Integrity — Computing systems should do exactly what they are supposed to do every time. Improved through innovative software development and smart hardware usage. Susceptible to attacks on the software, such as a buffer overflow attempt.
- Accessibility — Services should be easily accessible to users and should be able to handle sudden increases in number of users. Improved through actions such as upgrading servers. Susceptible to Distributed Denial of Service (DDOS) attacks.

Each of these ideas brings its own set of concerns and vulnerabilities. For instance, you can make data incredibly secure by completely restricting access to it, but this is in conflict with the idea of accessibility. On the other hand, making sensitive data extremely accessible, while convenient, is not secure and lessens the confidentiality of your system. These ideas became the core of our model of data and heavily affected our initial game designs, as discussed in the "Prototyping" section.

Responsible Disclosure is an important aspect of the information security assurance section of the CS2013 Curriculum. According to Heiser(2001), "The term 'full disclosure' is marvelously ambiguous, and therein lies much of the problem. It essentially means to 'widely disseminate as much information about system vulnerabilities and attack tools as possible so that potential victims are as knowledgeable as those who attack them.'" There is an important distinction that vulnerabilities, not exploits, are released. Vulnerability disclosure protects users by allowing them to make informed decisions on what cyber practices they partake in. To contrast, exploit disclosure primarily aids hackers who would seek to do use the exploits to their advantage (CERT Carnegie Melon).

Observations and Opportunities in Cybersecurity Education Game Design

We wrote and published a paper entitled *Observations and opportunities in Cybersecurity Education Game Design*. This paper was presented at CGames 2015, a conference about digital games from a programming practitioner's point of view. All of our prototyping and game decisions were made based on our findings within this paper (appendix A).

Our analysis of the literature and a survey of the state of the art contributed to a three-tier taxonomy for cybersecurity education games based on their method of incorporating cybersecurity content into game systems:

- Type 1* Games that convey cybersecurity concepts through narrative and/or theme only. There is no representation of the concepts within actual gameplay. That is, the act of playing the game does not require any decision-making that would reflect an understanding of cybersecurity concepts.
- Type 2* Games that integrate multiple-choice questions (including yes/no options and branching narratives) that correspond to cybersecurity concepts. Answering these prompts requires an understanding of concepts.
- Type 3* Games that require ambiguous decision making such that making good decisions implies an understanding of cybersecurity concepts.

We sampled 23 games: ten Type 1, five Type 2, and seven Type 3. Type one games are the most abundant, and, we suspect, the least effective group of games. Type two are electronic quizzes and arguably not games. We hypothesize that type three games are the most effective at conveying cybersecurity content and practices. Regardless of what type categories the games fell into, we found "bad" games in each of the categories. In fact, several of the games actually cross the line into absurdity.

Cyberbully Zombie Attack (Type 1) is a *Plants vs. Zombies* clone with a cybersecurity skin. Not only is this game ineffective at displaying authentic cybersecurity content, but it also dehumanizes cyberbullies. By displaying the bullies as mindless zombie, the game reinforces the othering effect that already exists with cyberbullying. Perhaps the only poignant representation within this game is that the teacher "plant" is asleep until a bully-zombie walks directly into their path and disturbs their slumber. The teacher proceeds to shout (and use laser vision) to damage the zombie, and then the teacher disappears, never to be seen again, leaving that same student vulnerable to attacks by other bully-zombies.

Safe Online Surfing (Type 2) has difficulty settings for grades 3-8. Regardless of the difficulty chosen, the student is presented with almost the exact same set of games with just slightly altered diction. For a game designed specifically for pedagogic reasons, it seems like a severe oversight to assume that eighth graders and third graders would benefit most from the same material presented in the exact same manner. The games range from a roulette style game that shovels terms onto the player to a time-

dexterity based game where the player is tasked with stopping a cyber bully, this time represented by a pirate crab holding a laptop with the word "bully" on the screen. Once again, we see a trend of literal dehumanization of cyberbullies.

CyberCIEGE (Type 3) is a simulation style game that is heavily rooted in cybersecurity and business practices. It is useful as a teaching tool, but it does not feel like a game. It is a plain simulation that never feels like there are any real stakes or conflict to contend with. The instructions tell the player what to do step by step, such as hiring a new employee or upgrading the servers and software, but there is no driving narrative to make the simulation *fun*.

Perhaps the most disturbing finding discussed in our paper is that there is a total lack of scholarly work on the efficacy of cybersecurity games. As explained by the paper, the few games that were at all mentioned in the literature failed to be tested in any sort of rigorous systematic assessment. As researchers and programmers, this is baffling and worrisome. Many of these projects claim to teach about cybersecurity, but these statements are empty without research that substantiates those claims. Even more irksome, several of these games are funded, directly or indirectly, by some government entity. This means that tax payer dollars are being used to create material that lacks substantiation to any of its claims of efficacy.

As a computer scientist, this lack of scholarly works highlights a trend I have observed in both my peers and professionals; software is created without any rigorous testing of its usefulness. In our classes, particularly our capstone series, we discuss "rigorous testing" and "quality assurance," but these deal with the program behaving in the way we intend it to behave. Our conversations then turns to limited user testing that often focuses on HCI (Human Computer Interactions) and design; this completely disregards the next step of taking the software that runs as we intend ensuring that it has the intended effects on or usefulness to our users. The software development process allows us to work in a bubble that ignores the fact that people are using our software.

Given the amount of bad cybersecurity games that exist and the lack of empirical data, there exists a niche that we set out to fill. We hypothesized that type three games are the most effective within our taxonomy, and we hoped to prove that through a qualitative research approach.

Prototyping

Prototyping a game is an arduous process; this difficulty was compounded by the inclusion of learning objectives. Because game design is a young field of inquiry (Burgun, 2015), we had to discover which genre best met our specific need through trial and error. We also had to consider our resources, capabilities, and the size our team.

After the completion of the epistemology, we began the process of paper prototyping, which allows for rapid iteration and testing. We believe that games and system must be rooted in the content (Klopfer et al., 2009). In our case, this means that the inner systems of games and game interactions should mimic the manner in which cybersecurity takes place. Our game design also needed to cover three different content areas:

- CA1: Cybersecurity jobs and education paths
- CA2: Cybersecurity practices
- CA3: Diversity in computing professions.

Cybersecurity and computer science professions and educational paths are often seen as difficult and unaccusable. As described by Hoffman:

The general perception [is] that computer science and STEM-related subjects are simply 'too hard' and take too much effort. This perception is found across the entire population, but is particularly reinforced among underrepresented communities, such as African-Americans, Hispanics, and Native Americans. (Hoffman, 2016)

Even further, in many states, there is no access to any sort of computing education and thus computing professions are not considered by children and teenagers. Based on this ignorance, the majority of students in our age range do not have any concept of how real cybersecurity practices take place. We seek to break down these barriers and expose the player to authentic cybersecurity content in a way that is accessible and interesting to the layman.

According to an NSF (National Science Foundation, 2012), the overall percentage of inbound collegiate students planning on majoring in computer sciences had dropped in recent years. There had also been a sharp decline in the number of computer science degrees awarded to women. Furthermore, the NSF reported that about 18% of computing science bachelors are awarded to minority students, even though the U.S. population is about 36.4% non-white (Hoffman, 2016). We want to address this through empathy and to make the field seem more accessible to minorities and women who may not otherwise have visible role models within a computing field.

It is useful for cybersecurity game development is the observation that real-life security is a competitive, asynchronous, distributed, asymmetric game. That is, security is:

competitive: opposing sides of attackers and defenders

asynchronous: each side may make its action at any time, regardless of what the other is doing.

distributed: the two teams are not collocated, although allies may be

asymmetric: the sides have different goals (win conditions) and take different actions

With that in mind, we hoped to take advantage of the ability of videogames to allow us to mimic the asynchronous property utilized in games like *Ingress*. We quickly decided, however, that the scope of such a project was beyond the capability of two man team within our time constraints. Cybersecurity practices are also competitive (attackers vs. defenders).

Dr. Gestwicki worked on several prototypes of a game informally titled *White Hat/Black Hat*, referred to as WHBH. White Hat is a term that refers to an ethical hacker, such a security professional who specializes in penetration testing and finding exploits in systems. Black hat hackers seek to bypass security for means that are unethical, such as personal gain or to harm someone else.

One iteration of WHBH was a three to five player asymmetric game, where $n-1$ players are White Hats, cybersecurity officials at software-oriented companies. They need to secure their companies assets. The last player is the Black Hat, a hacker who is simultaneously trying to capitalize on others' successes. The main tension in the game comes from the white hat players' desire to win while benefiting from cooperation, and the black hat player's ability to hide exploits and sow mistrust.

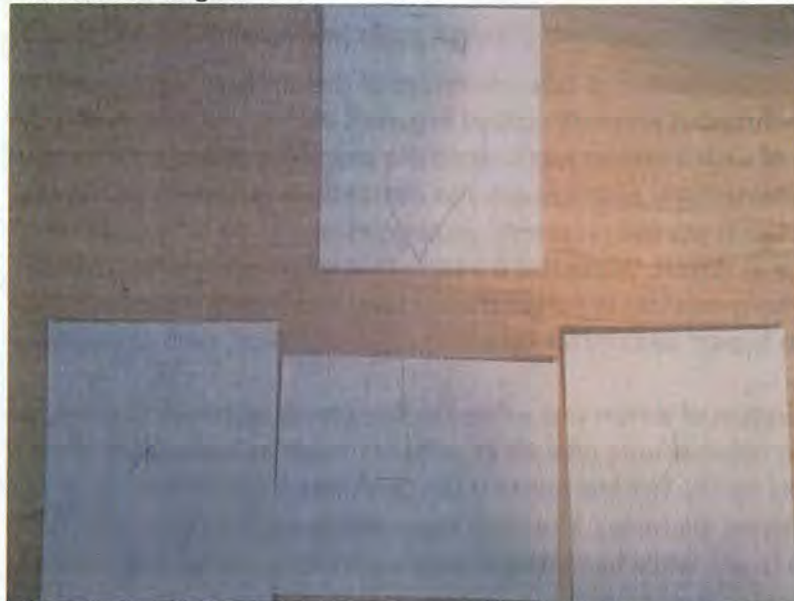
The other major version of *White Hat / Black Hat* was a competitive multiplayer networked video game in which players race to earn victory points by engaging in responsible

defensive cybersecurity activities (white hat) and malicious activities (black hat). A white hat hacker has to balance the business demands of their company against the need for confidentiality, integrity, and availability of their services. A black hat hacker seeks to find exploits and has to balance the risk of discovery against the increased rewards that come with patience. The main conflict in the game, then, comes from managing the unknowns: is your system compromised? Will you be attacked? Will your opponent discover your virus before you can gain valuable data?

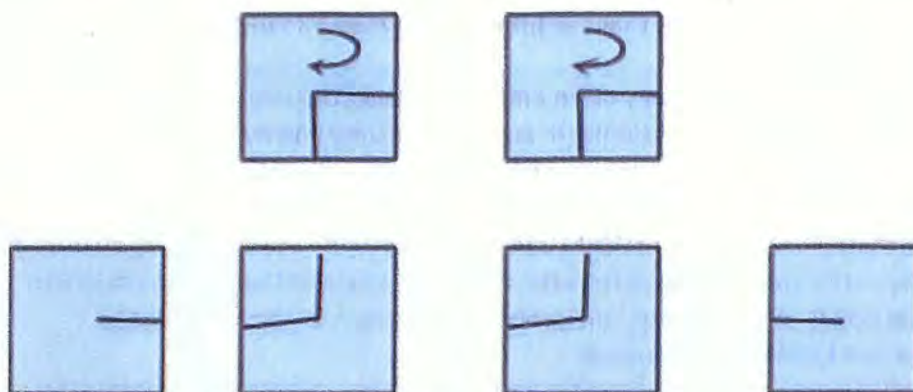
The game had both a white hat, black hat, and event phase. During the white hat phase, the player would seek to increase the security of their company through resource management. During the black hat phase, the player would attempt to steal valuable information by completing minigames whose difficulty was based on the strength of their target's security. The event phase would affect all players and was designed to allow for the inclusion of authentic, specific security events.

A single minigame was designed before this game was abandoned. The idea to capture in this puzzle game was that the exploit is made by forming specialized input. The following is an excerpt directly from our design document of that minigame:

The player is given a grid of tiles and has to lay new tiles atop them in such a way that execution (highlight) through the tiles reaches a desired end state. The tiles that are placed have a path and, optionally, a rotation command. When the execution hits the middle of the tile, the rotation command affects all adjacent tiles. Below is an example, where the bottom row is the given puzzle, with the start on the left and desired goal on the right. The player (black hat hacker) can solve the puzzle by playing a loop piece with a 90-degree clockwise twist. Note that when execution hits the twist command, the bottom-center tile turns, and the execution will come out and hit the target.

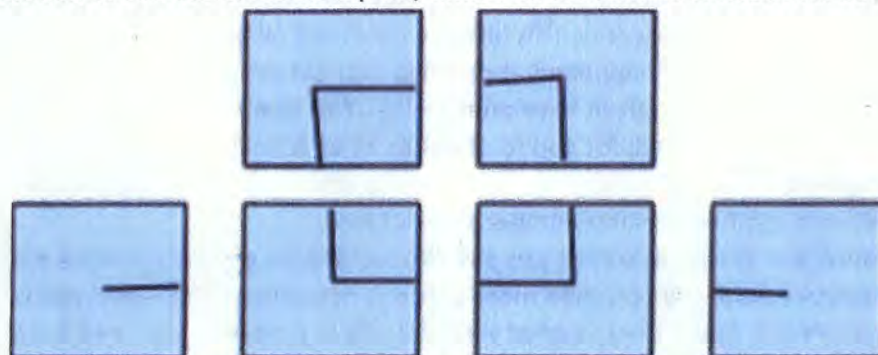


The puzzles can be generated in such a way that some have no solution, which is appropriate.



Note that a key element of this is the separation between *writing* the solution and seeing its *execution*. This gets into a programming-like mentality. Each puzzle could have a limited number of tries before it gets blocked off, based on the target's Integrity rating.

An alternative design was similar, but based on delayed response to input without specifying separate input. For example, given this puzzle, a solution would be to specify twists to the bottom-left and bottom-right spinnable tiles, then "play" the solution to see that it makes a path, similar to the format of *Robot Turtles*.



This design doesn't convey the duality of data and instruction, but that's abstract in the other version as well.

This minigame was designed as an abstraction an injection attack. As is briefly mentioned in the log, we attempted to discern what levels of realism or abstraction were acceptable and useful. With the second design of the minigame, we concede that "the design does convey the duality of data and instruction," but this does not necessarily mean the game is bad. We considered our educational goals, began to consider that perhaps an general understanding of cybersecurity ideas was sufficient, instead of specific, specialist knowledge.

The game's key purpose was to provide insight into both white hat and black hat perspective. White hat emphasizes tradeoffs of Confidentiality, Integrity, Availability, and Profit, as well as the source of profit in social networking software--users as product. The black hat hacking games include abstracted versions of buffer overflow/unsanitized input, social engineering, and password cracking with the hopes of teaching how these types of attacks

work. Upon retrospection, we decided that the programming work load to realize this project was too great for a two man team.

Since we talked about prototypes often and were basing out designs on the same body of source material, our prototypes are similar in concept but vary widely in execution. I worked primarily on a turn-based, multiplayer resource management prototype. The narrative concept was that the player was in charge of two different roles: a company and a black hat hacker. They had to make their company successful by raising money and wisely investing that money to up their security in the areas of confidentiality, integrity, and availability. As a black hat hacker, they would attack other players' companies in the hopes of gaining valuable information to sell and building a reputation.

At the beginning, the game was simple and had very few actions that could be taken. Besides being inauthentic, it was too simple to offer any compelling game play. I altered the game using an iterative process in which I slowly added and altered aspects of the game in an attempt at replicating actual cyber security practices. I obscured some information, including company defense ratings, black hat reputation, and stolen information value.

After many small, incremental iterations, I felt that the system was an accurate representation of cyber security. I began to work on game balance, which included altering the number of actions taken each turn, the strength of those actions, and the ease at which attacks could be successfully made. I grew extremely frustrated, at which point I received the following tips from Dr. Gestwicki:

- Keep turn logs when doing dry runs. This lets you play back what actually happened and not a misconception of what happened. It can help find patterns. I usually just do this on scrap paper, since they don't often have much value after changing things—they need not be very formal, just enough for you to separate what actually happened from what you think happened.
- Spreadsheets are helpful for many-number simulations
- Always balance and design as well as you possibly can before getting someone else to play it. Playtesters are giving you their most precious resource—time—so if you know something is broken, and it's key to what you're trying to evaluate, you need to clear that before you run a test.
- You need to playtest a game until you are sick of it, and then keep playtesting it. It's not fun—don't expect it to be. It's like QA in software.
- Remember that when something is hard and you don't know what kind of thing to do, the best thing to do is *_act_*. Fail as quickly as you can, because failure is learning. Not sure which of three approaches to take? Do all three, and see what you learn from it."

Beginnings of current game

These were crucial in motivating me to continue working on the game. Dr. Gestwicki was correct; I was sick of the game by the time I thought it had a reasonable balance. I informally playtested the game with several people, which resulted in further alterations and balance adjustments in the hopes of making the system less dense and more accessible, while still staying true to the content.

As I produced the final iterations, system patterns and ideal gameplay strategies emerged. I documented them as follows:

- Terminal Case- Too many turns, all company defense attributes upgraded to max level
- Slow Start- Because of the nature of money accruing over time, and stolen information value being based on company wealth and users, it behooves the player to just roll for high level exploits that can be used later.
- Blocking- In a two player game, one player can effectively block another play by never investing in obtaining users or marketing which makes them a viable target.
- Sudden End- Because of the nature of the game, all of the points are earned relatively near the end of the game. Instead of building up anticipation, it feels like being blindsided. Reminiscent of the end of Settlers, only less gradual.
- Optimal Path-Despite trying to play different ways, I gravitate back to a single play style that just seems to be the most efficient. Either that, or regardless of the order of moves, they end up being relatively similar in outcome.

In light of these observations, we decided to abandon this design. From our experience working on *Collaboration Station*, we know that local networking is difficult and programmatically intensive. Given the size of our team and the timeframe we wanted to keep, we decided to prioritize our work hours on game systems production. We transitioned from these game designs into a single-player, simulation style game. Popular games within that genre include *The Sims* and *Civilization*.

The decision to transition to the simulation style game was made out of necessity, but undeniably we lost a chance to create a learning environment. Games that include others, even as adversaries, allow for joint learning and the exchange of ideas. If one player has insight into a concept, they can share that with the other player(s), either during or after gameplay. Eliminating the multiplayer aspect also removed authenticity of cybersecurity, at least as it is controlled by the player. We were forced to instead mimic one side of cybersecurity, the black hat, on the back end, leaving the player to control only a single role.

Sim games rely heavily on the narrative to drive action and cause tension necessary for a game. We decided upon the story of the character playing as a cyber security professional at a budding social media company. We utilized CIA values in our original concept; these values are useful as a type of taxonomy for security actions and practices, but they are an abstract concept that is not critical and can be confusing the layman. Because of this, we replaced the CIA values with development and maintenance tasks/skills. This is the system we utilized in our game *Social Startup*.

Design and Justifications

The game begins with a set of four screen that set up the narrative from of the game. They say:

Social Jam is an up and coming social media service, and they have hired you as their chief security advisor. You were hired to manage a team of developers and protect the company from hackers! You have three employees. Assign them to develop features or maintain your current system. You have a job review in two weeks, and I expect us to have 50000 users by then. Make sure that we stay safe and our exposure doesn't go above 15%. Do you have what it takes?



Figure 1: Employee Designs

As explained by the introduction, the player has ten days to accumulate 50,000 users. The player must also manage their exposure, which increases as features are completed. If, at the end of the ten days, the player meets both of these conditions, they win.

After the introduction, the player is sent to the main play screen. The screen shows three employees that are randomly chosen from a pool of nine diverse possibilities (figure 1, appendix C). These characters were designed to be diverse in race and sex in an attempt to allow for empathy from players. We hypothesized that if a student saw an employee they can identify with, they would feel invested in both the game and the field. The wide range of employee would ideally allow a player to say, “they are like me! Maybe I could do this.” The intent is *not* to convince a player to follow a tech path, but rather to show them that that is a possibility that they could choose.

Before game time begins, the player must then navigate through the tutorial that is found by clicking on the flashing red notifications section in the bottom right hand of the screen (figure 2). This tutorial was designed to allow the player to figure out the system (with accompanying instructions) before their game timer begins. The player is told to change an employee’s task from maintenance to development and expand a character’s area by click on that character. Once in that area, they see a character’s educational history and a short, unique bio (figure 3) (CA1, CA3). After they finish the tutorial, the game clock begins.

The company has four attributes:

- 1.) Users over time- the amount of users gained per in-game hour
- 2.) Estimated Exposure- the likelihood of gaining an exploit every in-game hour
- 3.) Features- generate a randomized, set number of users per in-game hour between 50 and 200. Also adds a between two and seven percent exposure to the company upon completion.

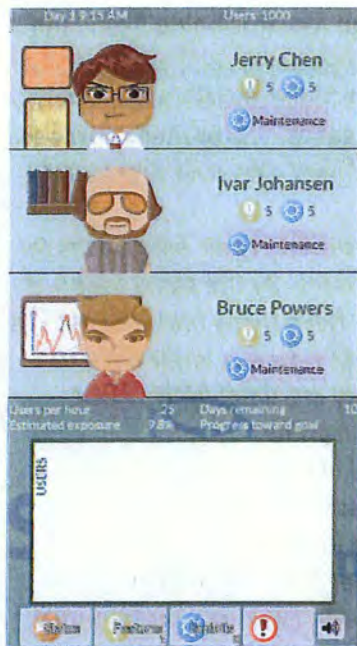


Figure 2: Narrative Alert

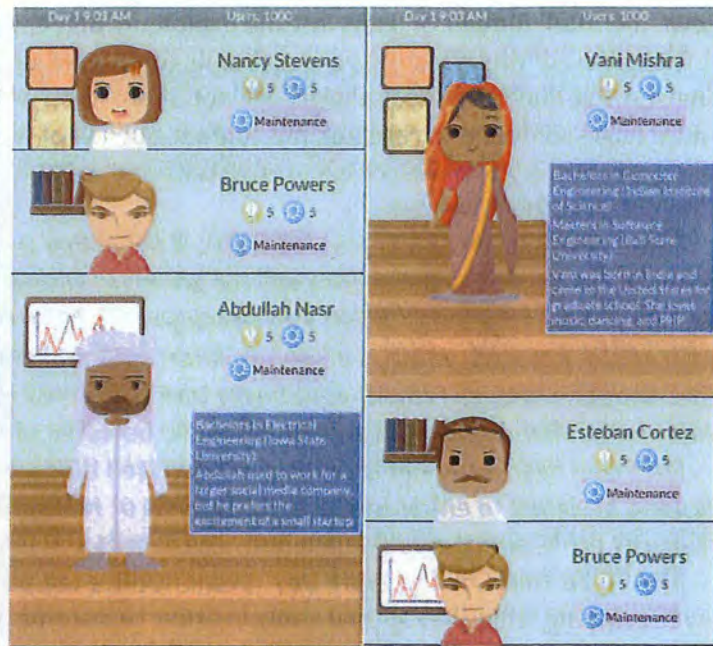


Figure 3: Character Bios

- 4.) Exploits- Chance to be generated every in-game hour equal to the company exposure. Drains 0.0022 of the total number of users per in-game hour until "fixed".

The employees have two primary actions and associated skills, and special actions:

- 1.) Development- generates progress towards the completion of the feature currently being generated. The amount of progress depends on the character's development skill.
- 2.) Maintenance- lowers the company's exposure and generates progress towards the fixing of defects.
- 3.) Special action- event specific action that ties up a character's work hours as they address the special circumstances instead of doing "normal" work.

The player can access all of this information through three of the tabs at the bottom (figures 4-6). On the features tab, they will see the names of features, their completion percentage, and the number of users per hour generated by each feature (figure 4). The exploit

| FEATURE | PROGRESS | USERS PER HOUR |
|-----------------|----------|----------------|
| Puppy Ville | 66% | 186.0 |
| User reviews | 100% | 77.0 |
| Cat Ville | 100% | 52.0 |
| Hollywood Ville | 100% | 190.0 |
| Puppy Ville | 100% | 25.0 |

Figure 4: Feature View

| EXPLOIT TYPE | USERS LOST | FIX % |
|---------------------------|------------|-------|
| Improper Input Validation | 240 | 0% |
| DNS Spoofing | 1731 | 0% |
| Privilege Escalation | 2250 | 0% |
| Session Hijacking | 2294 | 0% |
| Phishing Scam | 2374 | 18% |
| Cross-Site Scripting | 2001 | 100% |
| Weak Passwords | 2002 | 100% |
| Improper Input Validation | 1540 | 100% |
| SQL Injection | 1413 | 100% |
| Denial of Service | 420 | 100% |

Figure 5: Exploits

tab shows the total number of users lost the exploit, its percentage towards being fixed, and its name. The names of these features are authentic to cybersecurity content, such as cross-site scripting and SQL injection. Most players will not understand what these attacks are or mean, but it may cause someone to research the content outside of the game. The primary purpose in this case is exposure. All of the company attributes and a graph of user gain over time can be found on the status tab (figure 6-7).

These elements must be balanced (CA2). If the player leaves all of their employees on maintenance for the entire game, they will not generate enough users. By the same token, if they put all of their employees' effort into development, they will have many features but their company will be exposed, which is a lose condition itself and makes it nearly impossible to generate enough users, as exploits continually take users until they are dealt with. Their decisions in narrative events also greatly affect the outcome of the game.

Narrative events randomly occur at randomized times and in a random order. These events were designed to either model security ideas or replicate specific scenarios a cybersecurity professional would encounter. The events and their justifications are below.

The "Take Your Child to Work Day" Event notifies the player that the child of an employee is asking what they should study in order to become a cyber security professional. The player must then choose what to tell the child from a list of provided majors that range from computer science and mathematics to music and visual art. This was included as a measure to see if the players are cognizant of what subjects lead into a career path as a



Figure 6: Moderate decisions



Figure 7: Poor security decisions



Figure 8: Take Your Child to Work Day Event

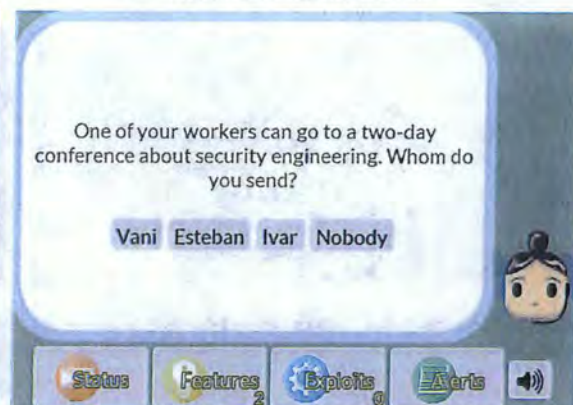


Figure 9: Security Conference Event

cybersecurity professional. Several of the choices are subjects that employees majored in, which can be found in their description box (figure 8). (CA1)

The "Data Stolen" Event alerts the player that user data has been stolen by hackers. They are given a choice of whether to alert their users or hide that the hack occurred. This deals with a recurring theme of "Responsible Disclosure" ("Computer Science Curriculum," 2013) addressed by the events. A cybersecurity professional is responsible for the security of data. In the event that that security is breached, they have a responsibility to alert those whose information was stolen. If a player decides to conceal the data breach, they lose a large percentage of their users, as opposed to a very small percentage if they alert their users of the breach. (CA2)

The "DDOS Event" addresses a specific type of attack in cybersecurity. A Distributed Denial of Service attack is when a hacker bombards a server with requests from bots, which pushes it past capacity and makes it inoperable. This event mimics this by making the player's service inactive for a number of hours equal to the player's company's exposure; during this time, the player stops gaining users. The player is again give then choice of telling their users what is going on, with similar results to the previous, except that they lose no users if they alert their users to the incident. (CA2)

The "Input Sanitization" Event displays educated, preemptive action. This falls within the realm of actual cybersecurity practices in that secure practices are put into place before any attack has taken place. The player is notified that one of their employees is concerned about injection attacks which may result from poor data handling. The player is also told that this would allow hackers to run programs on their machines. The player chooses between assigning someone from their team to sanitize the input or to ignore the issue. If they ignore, they are later alerted that they suffered and attack and have lost us ers because of it. (CA2)

The "Insecure Password" Event addresses one of the basics of safe electronic practices. The player is alerted that an employee from another department is using poor passwords, and as a result their station was hacked and user information was compromised. As the

Introduction Explains the game interface.

Take-your-child-to-work Day A coworker asks the player to recommend a major for his daughter to pursue in college.

Data stolen Choose responsible disclosure or secrecy when data is stolen by hackers.

DDOS Respond to an angry ex-user's initiation of a distributed denial-of-service attack.

Insecure password When a weak password causes a problem, choose whether to ignore it, fix it, or train the staff to prevent future problems.

Script kiddie Faced with amateurish attacks, choose to ignore it, report it, or fight back.

Security conference One employee may be sent to a two-day conference to improve their Maintenance Skill

Input sanitization When an employee expresses concern over input sanitization, you can either take action or tell them to ignore it.

Figure 10: Summary of Narrative Events

cybersecurity professional, the player is given the choice to administratively changing the employee's passwords or assign one of the employees from their department to train the other members of the company on how to create and maintain secure passwords (CA2). If they choose to administratively change the password, then this event is reregistered and occurs again after some time has passed. This was intended to show that education and training are an integral part of cybersecurity. An entity is only as secure as its least secure member. (CA1)

The "Script Kiddie" Event replicates an attack by an amateur who copied code they got online; the attack was unsuccessful, but the player must choose how they will react. They can ignore the attack (nothing), report it to the police (gain users), or send one of the company employees after the attacker as a retaliation (lose users). This was included to allow the player to make a morally charged choice. Having been attacked, was it ok for them to try and attack the hacker back? If they choose that option, they are alerted that their actions have violated the law and they lose most of their users for their short temper. This event attempts to incentivize the proper use of the authorities. (CA2)

The "Security Conference" Event was included as a measure of the player's prioritization of ongoing education. The player is alerted that one of their employees can be sent to a two day security conference. If they choose to send someone, that person is unavailable for two days, but comes back to work with a huge increase to the maintenance skill. There is no penalty for not taking part in this event, except that they don't get the long term benefit of having an employee who is incredible at the maintenance task (figure 9). (CA1)

Most of the events are obviously rudimentary and general. From past experience, we decided that a general literacy about cyber security concepts was more important than attempting to convey the intricacies of injection attacks, DDOS attacks, day of release attacks, and others. While our goal is not to teach about these specific attacks, the language used within the events and the exploits is authentic to cybersecurity content.

Social Startup Game is an HTML5 game that runs in modern evergreen browsers without plugins. The aspect ratio of the game makes it friendly for mobile devices such as smart phones and tablets, and the game scales to any screen size. The game is hosted at socialstartupgame.info; it is open source, and the central repository is at github.com/doctor-g/social-startup-game. The game was written in Java using PlayN (playn.io), which integrates with GWT (www.gwtproject.org) to compile the Java source code into HTML5 and JavaScript. Social Startup Game is a Maven project, and other libraries directly used by Social Startup Game include:

- TriplePlay (github.com/threerings/tripleplay), a library of utilities for PlayN-based games, including screen and UI management
- Mockito (mockito.org), a mocking framework for unit tests
- Google Guava (github.com/google/guava), a collection of useful libraries for Java
- React (github.com/threerings/react), a library for functional-reactive programming in Java

The game has a hybrid architecture, combining elements of traditional object-oriented design, an entity system, and functional-reactive programming. Most of the simulation is implemented within the entity system, which is a style of game engine architecture that offers many benefits over standard OO conventions (Gestwicki, 2012). Our implementation of entity system architecture is covered in the next section.

All of the programming and design were done by Paul Gestwicki and Kaleb Stumbaugh, and all of the artwork was created by Coy Yuan. The music is by Kevin MacLeod (incompetech.com) and licensed under a Creative Commons license (CC-BY-3.0).

Entity System Architecture

Because the word component and the component pattern have several meanings within software development as a whole, the component design pattern used within our game is referred to as Entity-System Architecture within this paper. As described by Nystrom, the purpose of ESA is to, ‘Allow a single entity to span multiple domains without coupling the domains to each other.’ This works in practice by placing the code for each domain in its own component class and then building an entity out of components; they are nothing more than a container filled with components. The same article by Nystrom lists three distinct times when you should use this design pattern: “you have a class that touches multiple domains which you want to keep decoupled from each other, a class is getting massive and hard to work with, [and when] you want to be able to define a variety of objects that share capabilities, but using inheritance doesn’t let you pick the parts you want to reuse slightly enough.” Our use was born out of best practices within the gaming industry; they utilize ESA because it is a computationally effective method for manipulating many fields and handling a lot of data.

Technically, ESA works rather simply. You create a set of components which in turn are used to build entities. Separately, you create systems that have all of the actual functionality.

| System Name | Function |
|--------------------------|--|
| EventTriggerSystem | Checks the registered events and triggers and event to occur if its registered time has passed |
| ExploitMaintenanceSystem | Produces progress towards “fixing” the oldest exploit based on the skill of the employee(s) assigned to the “maintenance” task |
| ExploitSystem | Generates exploits |
| ExposureReductionSystem | Reduces the company’s exposure value based on the maintenance skill of the employees assigned to the “maintenance” task |
| FeatureDevelopmentSystem | Increases the progress towards completion on current feature based on the “development” skill of the employee(s) assigned to the “development” skill |
| FeatureGenerationSystem | Generates a new feature with zero progress when the previous feature is completed |
| GameTimeSystem | Moves forward in real time but can be paused and unpaused; used by any other system that relies on time. |
| LayerPositionsSystem | Positions UI layers; original layout and removes employees when not during work hours |
| LearningSystem | Increases an employee’s skill over time as they perform a related task |
| TaskProgressSystem | Calculates the time remaining on special event tasks assigned to employees |
| UpdatingSystem | Updates entities; used as a model level support of updating UI components |
| UserAttritionSystem | Removes users per section per exploit equal to the product of the total company users and the exploit attrition value (0.0022) |
| UserGenerationSystem | Generates users per second equal to the sum of the user generation values of the completed features |
| WorkHoursSystem | Limits the work hours of employees to the common work day; accelerates time to twice as fast when not during normal work hours |

Table 1: Systems and functions

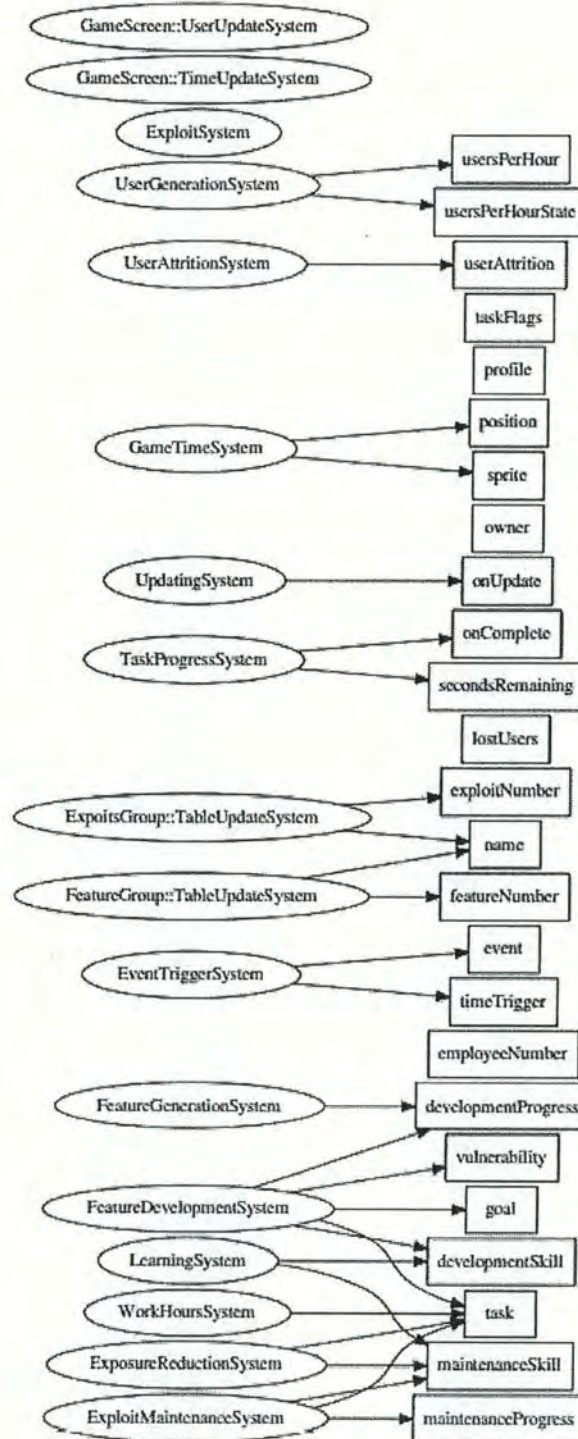


Figure 11: System (ovals) and components (rectangles) with arrows indicating dependencies

| | | | | |
|------------------|-------------------|---------------------|---------------|---------------------|
| employeeNumber | developmentSkill | maintenanceSkill | name | developmentProgress |
| goal | usersPerHour | onUpdate | timeTrigger | event |
| vulnerability | usersPerHourState | featureNumber | exploitNumber | userAttrition |
| lostUsers | profile | maintenanceProgress | sprite | position |
| secondsRemaining | owner | task | taskFlags | onComplete |

Table 2: Components

When a trigger event happens, such as a clock tick, the system cycles through the entities, decides which one it is interested in via a customized `isInterested` method, and does the appropriate actions to those entities who it is interested in.

The Social Startup Game was built utilizing the architecture. The systems and their purposes are explained in table 1. Components are listed in table 2. All of our entities are the sums of these components. For example, an event is composed of an event component and a timeTrigger. Employees are more complexed and are composed of seven components: employeeNumber, developmentSkill, task, maintenanceSkill, profile, sprite, and position. This is a perfect example of an entity that spans multiple domains: sprite and position are UI specific components, whereas development skill and maintenance skill, while displayed on the UI, are model level components. Employee number is only ever used in the model.

Our implementation of ESA had its struggles, and we were not sure if we had chosen the best architecture. Best practice in agile software development says that you solve a problem when it arises. While ESA is best practice in gaming currently, it is typically more useful on large projects where the frequency and number of calculations require data to be stored in RAM. Our game is computationally light and has a very small amount of data and assets. Regardless of this, we took advantage of the benefits of ESA in reducing coupling and avoiding DRY (Do not Repeat Yourself) violations.

The Study

The results of our IRB approved study (835177-1), The following is taken from our second technical report to SERC. The final draft will be published digitally by SERC.

I. Methods

To answer our research questions requires building an understanding of the player from descriptions and observations, and so we follow a qualitative methodology (see Stake, 2010, for example). The paucity of cybersecurity educational game assessments leaves almost no grounds for forming the reliable and valid instruments necessary for quantitative methods. Put another way, we could not know whether what we measured would actually contribute to answering our research questions. Cohen's classic essay highlights several methodological problems with applying statistical methods to human behavior, not the least of which is the common confusion of probability of data with probability of hypothesis correctness (Cohen, 1994). Qualitative research methods, by contrast, deal with observations and descriptions, meeting the subjects within their complex cultural contexts, and seeking understanding of phenomena that are not directly measurable.

| Subject ID | Gender | Age |
|------------|--------|-----|
| 1 | Female | 14 |
| 2 | Male | 10 |
| 3 | Female | 12 |
| 4 | Female | 11 |
| 5 | Male | 12 |
| 6 | Male | 15 |
| 7 | Female | 12 |
| 8 | Male | 12 |
| 9 | Female | 13 |
| 10 | Female | 16 |
| 11 | Male | 15 |
| 12 | Female | 10 |
| 13 | Female | 10 |

Table 3: Subjects

Our research protocol was approved by Ball State University Institutional Review Board (835177-1). Our subject pool consisted of thirteen youth, ages ten to fifteen, with eight females and five males (table 3). All of the subjects were white American students living in Indiana. They came from families who responded to a call for participation that was sent to Ball State University mailing lists and shared via social media. This group is a convenience sample of those who responded to the call, chosen for their ability to schedule sessions and with an emphasis on female participants. The subjects include a mixture of homeschool and public school attendees.

Each session consisted of a semi-structured interview combined with playtesting (Appendix D). Interview audio was digitally recorded, and these were transcribed into 918 paragraph-separated units. The investigators also produced 27 paragraphs of analytic memos, consisting of 1378 words. Gameplay behavior was automatically tracked using integrated logging, producing 16 logs consisting of 326 discrete game events. Interview data were coded using techniques inspired by Saldana (2013). The two researchers conducted three phases of coding before comparing results in order to ensure inter-rater reliability. The first round consisted of open coding, and these codes were refined in the second round. Appendix E lists our second phase codes, consolidated and standardized between researchers. The third round consisted of identifying categories, which represented the concepts that emerged out of multiple second-round codes; the categories are listed in Appendix F.

II. Findings

Our analysis resulted in four major themes, which are listed in figure 11. Each of the themes identified by our analysis are described in turn below.

Mixed views on the role of education and degree toward career goals

The subjects articulated a predictable mix of opinions about their school experience. Although the interview question about favorite school subjects was

- Mixed views on education and career goals
- Diverse opinions about developers appearance and interests
- Impact of background knowledge
- Two modes of character-driven decisions

Figure 12: Major themes

intended as more of an ice-breaker than anything, many students eagerly described what subjects they enjoyed and why. For example, subject 7 enjoyed English and science because they allow her to be “more creative than in other classes,” and subject 5 likes mathematics because identifies as “a problem-solver.” Subject 6 gives his favorite subject as lunch, since he is “not a big fan of school. . . I know I have to do it, but it’s not very fun.” We observe some subjects making distinctions between “academic” and “non-academic” courses: subject 9 prefers art and band, but she identifies English as her favorite academic course. We lack data to indicate whether this distinction is from schooling structures, environmental impacts (her mother is a teacher), or deeper knowledge of epistemology.

Our subjects showed a general understanding that mathematics is important to being a developer. According to subject 11, “There’s probably a lot of mathematics and, you know, how you have to know how games work or what other people did to make the games.” They also perceived Computer Science as being a default path into application development. Subject 6 says, “It seems like making an app would be more computers and that stuff than anything else.” During the in-game event in which players have to choose what major to recommend to a coworker’s daughter, ten chose Computer Science, two chose Graphic Design, and one chose Engineering—a surprising consistency of choices given that there were nine options (Table 3). Although almost all the students refer to Computer Science as the subject to study to become a developer, there is no other data to suggest that they understand what Computer Science is beyond a gateway to application development.

Some of the subjects recognized that a college education is not the only path to becoming a successful application developer. Subject 5 identifies reputation as an asset and entrepreneurship as a possibility, saying that “. . . somebody would hear about you, and you probably need to get a degree, or be an entrepreneur.” Subject 6 recognizes that coursework can help someone learn to make apps but that there is a wealth of “random sources” from which one can learn as well:

“If somebody decides they want to make an app, and they know how, they sit down and do it. If they don’t know how, and they still want to do it, then depending

on how complex the app is they either go to try to figure it out at some random source, or if it's a bigger, more complex project, they go take classes for it, and then they make the app."

Subject 4 recognized that teachers hold significant sway in students' opportunities. When asked how developers got their jobs, she suggested that "their teachers saw their ability to do something like that in an earlier stage, so when they were able to get the classes in high school and through college to be able to get better at that." This empowerment of authority is an interesting contrast against the entrepreneurial view described above, yet it reflects a real and common understanding of the trajectory from elementary school through to a career.

Diverse opinions about developers' appearances and interests

Most of the players claimed to have never thought about the physical characteristics of software developers, but among those that did, there was great variance. Subjects 6 and 13 reported developers to be "geeky," which matched our expectations based on earlier work on perceptions of engineers (Margolis and Fisher [2003], for example). Neither subject elaborated on what characterized geekiness, and we recognize that there are potential misunderstandings in leaving the terms used by teenagers up to the interpretation of adults. By contrast, subject 10 stated that app developers look "like normal people. . . like anybody." Subject 10 went on to say that the characters in the game "didn't look like smart people—they looked like normal people."

We did not expect the responses that painted app developers as something attractive and aspirational. Subject 7 describes them as "to sort of early 20s in age," only about five to ten years older than herself. Subject 9 was amused by Ivar's eccentric appearance, saying, "He looks kinda creepy, and I love it. I like his creepy long hair with a bald head." This was particularly amusing to us as Computer Scientists, given that Ivar was modeled after Bjarne Stroustrup, but we did not bring this up in the interview.

Subject 4 brings up a distinction between what she calls "designers" and "producers," which we believe to correspond to the business functions of application or interface design and programming. When asked what app developers look like, she puts it like this:

Well, I'm pretty sure [they look] like people, they're like artists and stuff, . . . I picture the people who design it would be kind of like artists, kind of, messy kind of regular people, and the people who publish it would be kind of like, official.

It is worth noting that subject 4 was one of several students who had completed a business information technology course in the local public school, which we know to have included an introduction to programming and which we believe to have informed students about some specializations in the field.

Subject 6 does not like school, but he does like Minecraft. When asked about the appearance of Minecraft's developers, he responds, "Probably most of them are not American, probably a lot of them are from Japan. It's a Japanese

company, isn't it?" While other subjects who brought up Minecraft seemed to know something about its Swedish creator, Markus Persson ("notch"), subject 6 held an incorrect belief that it was created by Japanese developers. We suspect that this belief may be due to the relatively high number of Japanese game development companies, this does not come up in the interview.

There was only one instance of overt sexism in the data: when asked why he sent Esteban to the security conference over Janine or Melissa, subject 2 responded cheekily, "He's the guy." No other subject referenced developers' gender in their discussion of their perceptions, backgrounds, interests, or educational preparation. However, we recognize that gender and racial prejudices may be subconscious or intentionally hidden from subjects' responses.

Impact of background knowledge

We saw players' background knowledge impact their in-game behavior and gameplay outcomes in a variety of ways. In a theoretical sense, this is unsurprising, given the wealth of evidence to support constructivism—the educational theory that individuals build their own mental models based on their experiences and background knowledge. However, the broad and multifaceted impact that this can have on educational game design and evaluation makes this worth analyzing.

Most players expressed surprise at the scale and persistence of cyberattacks. They were less clear on what the hackers were after. Subject 2 expressed a concern that revealed a few layers of confusion about the game, saying that perhaps the hackers "wanted to call the game their own." This shows an understanding of software copyright infringement ("piracy"), which then shaped his rationalization for their behavior. Although some subjects showed an understanding of the business and economic forces around software development, none of our subjects reflected aloud on the value of private information.

In the hacker event, most of our subjects chose to report the crime to the police. Subject 5, however, had a different perspective, saying this while playing the game:

I could report it to the police, or I could task someone to try to figure it out. I'll probably just task somebody to figure it out for now because, I don't really feel like getting mixed up with the police, so I'll task [someone] to do it.

We did not follow up to inquire why he did not want to get "mixed up with the police," but it stands in sharp contrast to those subjects who, seeing this option, quickly decided it was the best course of action. Subject 10 also chose to seek vengeance over notifying the police—an action that results in a tremendous loss of users—and in her post-game reflection, she regretted it: "No, I probably shouldn't have. I probably should have let the police handle it instead of taking it into my own hands."

Several subjects thought that decision points had right and wrong answers, and that their task was to choose the right one. This matches their experience with education and conventional educational games. Given that their interaction with us

was framed in terms of an educational game, it is not surprising that this mental model would be at the fore. Subject 11's explanation of how he approached decision-making in the game could just as well be about how he took a quiz in school: "I knew some of them would hurt me no matter what I did so [I chose] the best possible answers. And some of them, I really didn't know what to do, so I just guessed." However, we also observed some players adopting a more nuanced view, particularly those who played more than once. Subject 9 puts it this way:

See, last time I was like, "Oh, I'll let them know," and everyone got mad. So I thought I'd just keep it a secret. But then when I was exposed, everyone was like, "Why didn't you tell us that?!" They all got really mad and left me, which I think is what made my exposure go up. Last time they didn't like that; this time, they didn't like it more.

The players did not question whether the game was an authentic portrayal of a social media company, although they recognized the game as being a simulation. Subject 5 says, "I actually kind of liked it. I liked the way you have to try and run your company—I just kind of like that type of thing."

We observed the impact a role model can have on a player's understanding of software development as a profession. When asked about what the character's likely majored in, Subject 11 said, "My uncle has a job in computer software but he didn't graduate from college. So I don't think you have to." This is important when we note the disproportionate number of white, male software developers. If this indicates that those with a role model are more likely to be informed about IT as a profession, then underrepresented groups (women and people of color) who have relatively few role models are more likely to be unaware of how to become an IT professional.

Finally, we note that students' vocabulary and cultural literacy were major factors in their ability to understand the gameplay experience. None of the players younger than 14 understood the term "press release," although they were able to understand their options when we explained the term. Subject 5 demonstrated a general misunderstanding of core gameplay terms when, a few minutes into the game, he asked, "Are exploits and features good or bad, what are these?" Game literacy also played an important role, as it appears many of our subjects did not recognize the character skill levels for what they were. By contrast, upper-division high school players had no trouble recognizing these, and we can assume that older players would have broader game literacy.

Different modes of character empathy

The players often referenced their workers when making decisions. Several took advantage of the game's paused state to review the bios of their employees. We observed a dichotomy in how this information was used. Those who engaged in pragmatic decision-making chose characters who were deemed to be best at these roles. This is exemplified in subject 4's approach to dealing with the hacker event: "They needed somebody to fix it, so I sent [Vani] because she was good at fixing

that kind of thing.” Similarly, subject 7 explains why sent Jerry to investigate the injection attack, contrasting his background against Janine’s: “He seemed like the most well-trained out of all of them, and the girl—I forget her name—she seemed more like someone who should be with, like, social, and not developer, but Jerry seemed like the better person for the job of that kind of thing.” Sometimes this pragmatic approach included assumptions about educational background as well, as we can see in subject 11’s explanation of why he referenced their bios so often:

I thought there was probably a pretty balanced team, because you had someone who majored in three of the important categories, such as computer engineering. I can’t remember what the one in the middle was, and then there was another one who was good at working with people and finding out what they want. That’s why I chose here to do the—oh no, I chose the engineering one to teach people how to do the password thing because he know how to make a safe password, and then I would have chosen her to find out what people liked. . . .

The other mode of character-based decision-making was empathic: some players justified their decisions based less on a desire to maximize output and, instead, based on a feeling of helping the fictional characters feel more fulfilled. Subject 9 is the best example of this—an enthusiastic player who quickly learned the characters’ names, referenced them frequently, and seemed particularly interested in being a good leader to them. When we asked why she chose Janine for several events, she told us, “From her description, she seemed really on it. She seemed really cool. I liked her a lot.” Subject 9 also commented on how much she liked Nancy, explaining that she saw some of herself in Nancy’s artwork:

She looked really sassy. And she looked like me before I went insane, ‘cause I used to have long blond hair and that was normal. It was gross. But she was really sassy, so I liked her. ‘Sassy,’ like, not really sassy but, like, ‘cool.’ Like, she looked hip and with the kids.

It is worth adding that, when subject 9 was first reading Nancy’s educational credentials, she had other reasons to identify with this character: Nancy and the subject’s mother shared an alma mater, and she was also impressed with Nancy’s hobbies, saying, “Nancy has a popular podcast about being a woman in technology. Oh, that’s cool!” Our data are not clear on whether sharing a gender contributed to this identification as well, but we note the possibility.

III. Discussion

About the game

Our findings regarding game vocabulary affirm our design decision to avoid the terms “confidentiality”, “integrity”, and “availability” in the game. These are undeniably security jargon, not common parlance. The subjects in our study were not a random sample of their age group, and in fact, we have reason to believe that these were children of privilege; we expect that players’ confusion over vocabulary

and cultural references would be exaggerated among players from less privileged backgrounds.

The Social Startup Game features high degrees of randomization in the spirit of increasing replayability. For example, the sequence of story events and the set of characters included in the game are randomized, so they will be unpredictable for any given gameplay experience. However, we confess that while this improves replayability—generally considered a virtue in games of any kind—it also potentially hindered our evaluation. Each player was faced with a random set of characters, for example, so we cannot directly compare two players' opinions of their workers to each other, and we also could not intentionally match or mismatch character gender and ethnicity with the player.

A significant category in our analysis included usability problems with the game interface. The two that dominated the list were players not realizing that they could change characters' tasks and that they could read character bios. This surprised us during the first few interviews, given that all of the players read this introduction given by Frieda, Social Jam's administrative coordinator:

[Employee 1], [Employee 2], and [Employee 3] are currently maintaining our software. You can tap them to find out more about them. You may reassign any number of them to new feature development at any time. Go ahead and try that now, and let me know when you are ready!

All of the players read this and then tapped "Next" without ever following her instructions, except for those whom we interrupted to demonstrate how to do these actions. This usability problem could likely have been discovered with more playtesting prior to the formal evaluation. However, we do not believe that this had any invalidating effect upon our findings, since players were quick to understand the interface once we demonstrated how to use it. We suspect part of the confusion came from the fact that our interface was designed for touch-based mobile devices, yet our evaluation was being done on non-touch laptops with mouse input.¹ We observe with mouse-driven input that players scan the screen with the pointer, watching for responses that would indicate interactivity, whereas on touch-based devices, players are more apt to try tapping things to see what happens.

We used *The Social Startup Game* as part of our workshop at the 2016 Congressional Leadership Academy, which is a full-day event for high-achieving high school juniors from Indiana's sixth district. The students at this event, who were just barely outside of our target demographic, showed none of the confusion over terms and jargon; in fact, they seemed to enjoy the game much more than our target demographic. Of course, these were high-achieving students who elected to attend a session on cybersecurity, so in a sense we were preaching to the choir: these students were already on their way to potential careers in cybersecurity.

¹The reason for using mouse-driven input was an untimely defect in one of our supporting libraries. PlayN's 2.0-rc3 contains a previously unidentified defect that broke popup menu support on touch-input devices, and hence player role selection was impossible on touch-based interfaces. Although PlayN 2.0 has yet to be released, the snapshot build has fixed this defect, and our current version of the game is built upon that snapshot.

About security and software development

As described in Section 2, our game veered away from the fine-grained security concepts explored in games such as CyberCIEGE (Irvine et al., 2005) toward authentic contextualization of relevant decision-making. We saw variation in how subjects approached their initial choices, informed by their individual backgrounds, but we also saw a move toward more ethical and informed decision-making after playing the game. This was especially pronounced when considering the principle of responsible disclosure. In the absence of a longitudinal component to our evaluation, we do not know whether these students will later recall specific kinds of attacks introduced in *The Social Startup Game*, such as injection and DDOS attacks.

Our players who had previous exposure to programming believed that they could get a job in software development. This is an important victory for advocates of early computing education intervention. One homeschooled subject mentioned having a positive experience with Code.org, while several public-school subjects cited positive experience with Scratch3 through a required business information technology course. Subjects with no exposure to programming showed more anxiety or unease at the thought of software and IT careers. It merits repeating here that ours was not a random sample: our subjects came from families who were willing to bring them to an educational game evaluation, and all our subjects identify as “white.” Fortunately, there are ample other programs—even within our own community—that are building local theories around ethnic minorities and specifically targeting families of low socio-economic status. Despite this caveat around ethnicity, we observed no significant difference in opinions or articulations between our male and female participants. We hope that this points to a continuation of the trend toward greater gender diversity in Computer Science programs and, by extension, into industry.

About education

The number and confidence of players who chose Computer Science as the default academic option for IT careers is problematic. While it is true that many students graduate from Computer Science programs do pursue such careers, we know that there are many other ways to get there. Anecdotally, we have met recruiters who

prefer liberally-educated, critical-thinking philosophy majors over myopic, code-oriented Computer Science majors. If there is any standard of what constitutes Computer Science, it is the ACM/IEEE Curriculum Guide (Computer Science Curricula 2013)—a sprawling guide that speaks to the truth of the insider joke, “If you ask five computer scientists to define ‘computer science’ you get seven different answers.” We are starting to see new programs being developed, including Software Engineering programs and transdisciplinary programs like Georgia Tech’s computational media major. However, the fact remains that to many students, computer science has “computer” in the title, and it looks to them like the one surefire path toward software development careers.

We believe there is reason to be concerned about the perception that subjects in school are either “academic” or “not academic.” Our study does not reveal from whence these youth developed such perspectives, although we can assume that it relates to the administrative structure of their school experience. The divisions of school are artificial, created by bureaucracy for the purpose of perceived efficiency. Students who do not recognize this as an artificial construction become, ironically, victims of it rather than liberally educated.

Although this study is aimed at youth, our experiences with undergraduate computer science students revealed to us a connection between our subjects and our university students: understanding of security principles and practices is negligible, and both pools seem to lack the concepts—the vocabulary—about which to converse on these. This echoes the findings of the Cybersecurity Education Workshop [Cybersecurity Education Workshop]. We suspect that there is a causal relationship between the prevailing structures of Computer Science education and the lack of good security practices in industry. The ACM/IEEE curriculum guidelines for Computer Science curricula treat cybersecurity differently from all other domains, explaining that this topic must be included throughout the curriculum and not simply in isolated courses. However, conventional higher educational structures privilege the separation of content into courses as well as the academic freedom of faculty in the classroom. This leads to a situation where there is no practical way to create interleaving topics, motivate their adoption, or evaluate their efficacy.

About game design

Those who made pragmatic character-based decisions did so assuming that character backgrounds impacted their performance, while in fact, all of the characters are interchangeable: the differences between them are only skin deep. It is interesting that the same players who lacked game literacy to recognize certain design tropes (such as a character statistics block) did assume that character backgrounds provided some kind of hint to maximizing decision outcomes. Considering two design options—one in which characters are all fundamentally the same regardless of their appearance, bio-sketch, and credentials, and one where their in-game behavior is different based on these factors—we lack data to determine whether one will better meet our intended learning outcomes.

The discovery of empathic character-based decisions opens more potential opportunities for future design research. Our prototyping process included several different quantitative factors such as users, defects, and money, but none of our approaches considered emotional health, such as happiness or job satisfaction. Players who tend toward empathic decision-making may feel more engaged with the game by receiving such feedback, and this, in turn, may lead to better learning outcomes. Inspired by Bartle’s classic essay (Bartle, 1966) in which he describes the kinds of players who play MUDs, perhaps a similar kind of taxonomy could be built that describes how players approach decision-making with respect to fictional, in-game characters. We know of no such theory, but our findings suggest that it could be quite useful for game design generally and educational game design specifically.

Many players made decisions based on a search for the “right” answer, not just a good answer. We suspect that there are two factors that contribute to this mental model. First, the game was framed as an “educational game”, which is something of a loaded genre. Klopfer et al. [2009] describe the history of educational games and their many problems. One common design mode is to rely upon multiple-choice, quiz-style assessments, where there is just one right answer. We explored how this phenomenon affects cybersecurity games in particular in our earlier work (Gestwicki and Stumbaugh, 2015a). Such assessments ignore constructivist and situated theories of learning (see Hickey and Zuiker (2003), for example). More to our point, they put students into a school-culture mental model that multiple-choice scenarios imply that there is only one correct answer. The second factor we suspect to contribute here is the predominance of such dichotomous decision trees in computer games. From our experience, games aimed at youth tend not to feature nuanced decision-making, particularly in dialog options. Hence, a player whose mindset is one of conventional games would not expect, say, that the advice given to a coworker’s daughter did not have any “wrong” answers.

As mentioned earlier, we had the opportunity to introduce several high school juniors to Social Startup Game through the Congressional Leadership Academy. While this was not part of our formal evaluation, we noticed an interesting phenomenon that is worth noting here. This portion of the academy was held in a computer science teaching lab that is designed for pair programming, and so based on the furniture configuration, the participants formed pairs around workstations. Each play through the game was therefore completed by a pair of participants—strangers who had only met that day. Although they were not instructed to follow a think-aloud protocol as were our actual research subjects, they played the game much slower and more deliberately, seeking consensus among the two players before making any move. We believe that this points to an important possible direction for future evaluations of such pro-social games. This kind of situative perspective—drawing upon the tradition of Wenger [1999]—could reveal important truths about the subjects and their play experience (Hickey and Zuiker, 2003).

Conclusions and Future Work

The design goals of this project were to create a game that teaches fundamentals of cybersecurity and to expose careers and career paths to cybersecurity careers. Regarding the former, we found that the topic of computer security poses significant challenges to the design of educational interventions, particularly because security is woven into the tapestry of professionalism in software development. While it’s true that cybersecurity can be a focused area of study—as evidenced by courses and certificate programs—to understand security requires an operational understanding of the rest of the system. This property of cybersecurity is the reason why the ACM/IEEE Computer Science Curriculum guidelines uniquely identify information assurance as needing to be integrated through other courses;

this is especially surprising given the conventional, course-structured approach for the rest of the curriculum guide.

Despite these challenges, our rapid prototyping process identified several possible mappings from cybersecurity concepts to learning game mechanisms. A limited production budget and schedule contributed significantly to the selection of ideas that constitute Social Startup Game. Future work should more rigorously explore the asynchronous, asymmetric, multiplayer mechanisms that were out of scope for this project, since these properties are integral to computer security—we suspect they represent the best effort to “find the game in the content” (Klopfer et al., 2009). The context of deployment and evaluation is also worth investigating, particularly extending to more situated environments, adopting more wholeheartedly a design-based research approach (Brown, 1992, Barab and Squire, 2004).

Regarding the second design goal, our evaluation has served to confirm the value of early computing interventions toward positive outlook of youth toward computing careers. Our subjects recognized the economic viability of computing careers. However, this was coupled with a wide variety of perspectives of the developers themselves: some positive and aspirational, some negative and stereotypical. Taking Social Startup Game as a pilot project, future work could look more carefully at how both aesthetic and formal properties of in-game characters can change perspectives of players toward real-life software developers and IT careers. Our findings present a snapshot, a local theory on how youth perceive software development careers, and future work can compare this to other times, places, and contexts.

This work validates our hypothesis that a Type 3 cybersecurity education game would be useful for addressing our design goals (Gestwicki and Stumbaugh, 2015a). Social Startup Game puts the player into an authentic although simplified simulation of a software development start-up company. Players made decisions based on what was best for the company, aligning in-game victory with successful decision-making. They identified with the in-game characters in rich ways, making both pragmatic and empathic choices in their attempt to win. This produced a corpus of data that led to important, interesting, and sometimes surprising findings—findings that we believe would not have been possible in a Type 1 or Type 2 experience. This work therefore provides an example of and a justification for formal evaluation of cybersecurity education games.

What I would do differently

The beginning of each Scrum retrospective meeting begins with The Retrospective Prime Directive. It is prudent to include that directive: “Regardless of what we discover, we understand and truly believe that everyone did the best job they could, given what they knew at the time, their skills and abilities, the resources available, and the situation at the time” (“Retrospective Prime Directive,” para.4). As is the case in all projects, software or otherwise, retrospection revealed actions and methods that would have been preferable to what we

actually did. As a two man team, this is not surprising, as it is easy to fall into a pattern of assumed correctness without someone presenting a dissenting opinion.

As discussed in the previous section, we often had to explain the user interface of the game. This obscured the results of the testing, as we had to decide if actions and difficulties were a result of the content or a lack of understanding of how to navigate the UI. In retrospect, we should have dealt with the UI through informal play testing before attempting the formalized qualitative study of the game's efficacy. This would have made the data we received from the study more clear.

As I experienced with while prototyping, game balancing is an arduous and frustrating task. Brian Green, a programmer and game designer known for his game entitled *Meridian 59*, offers some insight into the complexity of game balance:

Balance can be difficult because you have to consider how all these subsystems in the game work together. For example, In an RPG, the design and implementation of a subsystem for equipment will greatly affect the combat subsystem of the game and perhaps others. Therefore, a change to equipment will have consequences for how the combat plays out and it is vital that a designer understand how changes in the one subsystem affects the others. We can also see second order effects, such as a change in what treasure a monster drops indirectly affects the combat system because of what gear is available to the player. This means not only considering the consequences in design, but also testing for those differences in how the game actually plays. (Green, 2016)

Even for an experienced game designer, balancing a game can be difficult, as is apparent in Green's writing.

The Social Startup Game was created in parts. We created user generation and user attrition through features, exploits, and the associated systems, and then immediately added worker tasks and abilities. We then added events, which complicated the system. When we reached the point of balancing the game, I felt as though the systems had become large and untraceable.

Green discusses three methods of balancing non MMO, incrementally developed games: balancing as each feature is added, balancing periodically, and balancing continuously. We balanced periodically, which allowed us to schedule and control the amount of time we spent. Green identifies a downside to this method as, "this may leave you with a lot of little lingering issues that could add up in the end. A small problem...may become much more important..." (Green, 2016).

If given the chance, I would attempt to continuously balance the game. This is limited by "the finite nature of time and development schedules," but small changes can be quickly found before they develop into larger issues. Because we were both testing and developing, we would not have encountered a major pitfall of this method where feedback from testing is push off until later (Green, 2016). I cannot say for certain that using this method would be overall more beneficial, but I was unsatisfied with the method we used as it applied to this project and so would attempt something else.

Overall, I would change very little about my experience with this project. I made many mistakes, but as Dr. Gestwicki reminds me, "failure is learning." The freedom to ask myself "what would I do differently?" is imperative to learning and growth.

Why this work matters

We began this project with a clear foundation of beliefs upon which the project could grow. We understand that games are rapid feedback systems that can be used as tools for learning. We also understand that there is a lack of knowledge about and interest in cybersecurity and computer science in middle schoolers, particularly among females and minorities. Finally, we know that the games that already existed prior to this project with the purpose of teaching about cybersecurity have no academic research proving their efficacy. This seeks to address those concerns.

Personally, this work has also been instrumental in shaping my collegiate career. Because I began working on serious game design after only my first three computer science courses, the intersection of games and computing seemed natural. This project was an obvious culmination in that progression. It has exposed me to formal research methods and the IRB process. I have also had the opportunity to work closely with a programmer who thinks critically. He also has many years of experience, education, and a carefully cultivated thought process that I was able to observe and utilize in refining my own practices. I am more rounded and practiced as a programmer, a computer scientist, and an academic because of this experience.

Appendix A: Observations and Opportunities in Cybersecurity Education Game Design

Observations and Opportunities in Cybersecurity Education Game Design

Paul Gestwicki and Kaleb Stumbaugh
Computer Science Department
Ball State University
Muncie, IN 47306
Email: pvgestwicki@bsu.edu

Abstract—We identify three challenges in cybersecurity education that could be addressed through game-based learning: conveying cybersecurity fundamentals, assessment of understanding, and recruitment and retention of professionals. By combining established epistemologies for cybersecurity with documented best practices for educational game design, we are able to define four research questions about the state of cybersecurity education games. Our attention is focused on games for ages 12–18 rather than adult learners or professional development. We analyze 21 games through the lens of our four research questions, including games that are explicitly designed to teach cybersecurity concepts as well as commercial titles with cybersecurity themes; in the absence of empirical evidence of these games' efficacy, our analysis frames these games within educational game design theory. This analysis produces a three-tier taxonomy of games: those whose gameplay is not associated with cybersecurity education content (Type 1); those that integrate multiple-choice decisions only (Type 2); and those that integrate cybersecurity objectives into authentic gameplay activity (Type 3). This analysis reveals opportunities for new endeavors to incorporate multiple perspectives and to scaffold learners' progression from the simple games to the more complex simulations.

Keywords: cybersecurity education, educational games, game analysis, game design

I. INTRODUCTION

The 2014 Cybersecurity Education Workshop Final Report [1] highlights several areas for growth and development in cybersecurity education. We were inspired by the *Concepts and Conceptual Understanding, Assessment, and Recruitment and Retention* recommendations in particular. The first deals with conveying fundamentals of cybersecurity, not just to information technology professionals but to anyone whose work intersects modern technology—that is, practically everyone in the developed world. A challenge posed by the report is to deal with the fundamental epistemological question: what is cybersecurity? The second deals with the problem of assessing efficacy of educational interventions. That is, if we design a cybersecurity education intervention, how do we know that the participant has learned something? Of particular interest is transfer: it is not sufficient for the learning to be embedded only in the intervention when the goal is to affect behaviors outside of it. The third recommendation inspiring this work deals with the pipeline problem. Maintaining our current technology and information infrastructure requires a critical

number of well-prepared knowledge workers. Beyond maintaining current systems, making continued progress in research and development requires knowledge workers with an even deeper understanding of the sociocultural and technological systems at play.

Game-based learning is one approach to addressing these three recommendations. A variety of educational games around topics in cybersecurity already exist, including online games for children, digital training simulations, programming competitions, and analog games. We are interested in identifying the strengths of current approaches with the explicit goal of identifying new opportunities. That is, we believe that if we understand cybersecurity and what learning outcomes are supported by current generation educational games, then we can identify pragmatic approaches for developing next generation solutions.

This work focuses on games for youth around ages 12–16. These are formative years in which individuals' perspectives about careers and technology are formed (see Margolis and Fisher [2], for example). Potential players in this age range are usually ingrained in rigorous formal and informal learning environments, and so there are opportunities to incorporate interventions around the *Concepts and Conceptual Understanding* and *Recruitment and Retention* recommendations. Game-based learning strategies could also address these recommendations with an older, adult population as well, but this is beyond the scope of our study.

II. BACKGROUND AND RELATED WORK

A. Cybersecurity and Epistemology

The Cybersecurity Education Workshop report identifies the need for an epistemology of cybersecurity [1]. That is, promoting cybersecurity education benefits from a coherent definition of the term itself, as well as an articulation of what is known—or what is knowable—about it. A recent National Academies report identified both technical and sociocultural elements of cybersecurity [3]. Technical elements include computers, networks, and cryptography, and sociocultural elements include policies, trust, and social engineering. Kessler et al. [4] describe cybersecurity as a subset of information security, itself part of the larger domain of information

assurance. They further recognize that cybersecurity is about process—not technology—and so a STEM (Science, Technology, Engineering, and Mathematics) perspective is insufficient. They assert that “our response to cyberrelated security challenges of the day are not solely about technical solutions but must also involve a myriad of related topics such as national defense, economics, sociology, political science, diplomacy, history, and many other social sciences” (p.36).

A similar conceptualization of cybersecurity is reified in the Computer Science Curricula 2013 (CS2013) recommendations, particularly the Information Assurance and Security (IAS) knowledge area [5]. The IAS area is unique among those in the report in that its topics are pervasive throughout the other knowledge areas: the recommendation includes only nine core areas that are strictly IAS, but 63.5 hours of IAS concepts are distributed among the other knowledge areas. The epistemology represented by this recommendation is particularly useful for our analysis due to the inclusion of both concepts and learning outcomes. The learning outcomes are further classified using a system inspired by Bloom's taxonomy of the cognitive domain [6] in which each objective marked with one of three levels of mastery—familiarity, usage, and assessment—which map roughly to Bloom's levels of understanding, application, and evaluation. It is worth noting that these recommendations are approved by a large panel of recognized experts across both the ACM and the IEEE. For these reasons, our own work uses these recommendations as a primary reference for cybersecurity epistemology.

B. GAMES AND LEARNING

We approach games and learning from the perspective that games are rapid-feedback systems, and since timely and appropriate feedback is a necessary element for learning [7], [8], we see games essentially as teaching machines. Koster [9] describes how learning is an essential aspect of what we call “fun” in games. Built upon Csikszentmihalyi's concept of *flow* [10], Koster's Theory of Fun for Game Design argues that games teach players to overcome challenges, and “fun” arises from the balancing of skill and challenge. Swink [11] uses a similar argument from an aesthetic perspective, arguing that *game feel* comes in part from designing a game as a

teaching system that produces, in players, both learning and a feeling of accomplishment.

The goal of formal educational systems is *transfer*—that what a student learns in one context can be applied in another. This is a particular challenge for games, where the learning is necessarily embedded within the formal and dramatic elements created by the designer. Linderoth [12] describes how it is a matter of affordances, following the ecological model of perceptual learning [13]: to act meaningfully in the world requires the recognition of an affordance, the taking of an action, and the capacity to receive feedback on the action's impact. Consider *CyberCIEGE* [14] for example—one of the games that we reviewed that presents the user with a simulated work environment. The game affords learning about cybersecurity within the realistic yet simulated game world, where the operating systems, software products, people, and governments are abstract and fictional. A player may earn high scores in *CyberCIEGE*, but if the player cannot apply this learning outside of the game environment, then the product fails at its fundamental design goal.

A review of the literature revealed no scholarship evaluating the efficacy of existing cybersecurity education games. For most of the projects we evaluated, there is no mention of them in the literature whatsoever. Others, such as Irvine et al. [14], Twitchell [15], and Nagarajan et al. [16], justify their respective design decisions within various theoretic models, but without the rigor of systematic evaluation or assessment data. While the authors claim to be following reasonable practices, these claims lack substantiation. While we agree with Stokes et al. [17] that it is divisive to claim any one definition of “impact,” we remain concerned that many of these projects are taxpayer-supported and have produced no evidence of success or rigorous standards.

Good design practice, then, is essential, although this is one of few truths recognized among educational game designers. The draft report by Stokes et al. [17] describes the field as one of deepening silos and fragmentation, in part because of failure to recognize the various multidisciplinary and interdisciplinary perspectives that come together in this space. Klopfer et al. [18] survey the history of educational games and provide sound, research-based strategies for designers, and these strategies informed our analysis methods. These specifically address our first

recommendation from the Cybersecurity Education Workshop report [1]; to address assessment, we turn to research-based approaches such as those described by Hickey [19] and Mitgutsch and Alvarado [20].

We note that the classification of learning objectives in CS2013—described in the previous section—are particularly applicable for the design of game-based learning environments. *Familiarity* can be included through a game's formal or dramatic elements. *Usage* manifests as actions the player can take—that is, these are the mechanics of the game, where one finds the game in the content [18]. *Assessment* represents a conceptual abstraction that requires extended abstract reasoning [21]. A game may encourage players to reach this level of understanding through clever mechanics design; however, this may also represent an opportunity for the use of debriefing as a post-play learning activity—an approach that has been shown to bring rich, higher-level learning results from game-based and simulation-based experiences [22]–[24].

Burgun's taxonomy of interactive forms [25] provides a useful framework from the context of game-based learning. His taxonomy identifies four forms: a system without goals is a *toy*; adding a goal yields a *puzzle*; further adding competition yields a *contest*; and finally, adding meaningful ambiguous decisions yields a *game*. It is important to note that his use of these terms is descriptive: he does not claim that all things called a “game” fit his taxonomy this way, but rather that what *he* calls a “game” is described as given—an approach that respects Wittgenstein's argument that the word cannot really be defined anyway [26]. Burgun's taxonomy is useful because it allows for an unambiguous classification of artifacts based on their designed properties: an interactive composed entirely of multiple-choice questions is a *puzzle* where the player attempts to pick the right answer. The learning value of such digital tests are limited compared to those that realistically embed a context into in-game experiences. For example, Hickey et al. [27] describe how incorporating real scientific inquiry into *Quest Atlantis*—thereby making it a *game* in Burgun's taxonomy—also increased the learning gains significantly.

III. ANALYSIS

We focused our analysis on these research questions:

- Q1 Does the game include cybersecurity content?
- Q2 Do the game mechanisms directly support the learning objectives?
- Q3 Does the game describe careers in cybersecurity?
- Q4 Does the game explain educational paths toward careers in cybersecurity?

The first question was used as a sieve to identify what games we would consider for analysis. We acknowledge that there may be games that legitimately teach cybersecurity concepts despite not including it as a theme, this was beyond the scope of this work. The second question was used to allow us to more easily identify trends among similar games: by looking more critically at the game mechanisms, we can identify which follow the advice to find the game in the content. Specifically, we look for evidence that the game mechanisms are tied to authentic cybersecurity education learning outcomes [5], following Klopfer et al. [18] and Hickey [19]. To be clear, we mean “mechanisms” in the sense of formal elements—the game components with which a player directly interacts, as opposed to dramatic elements that frame the play experience [28]. The third and fourth questions tie explicitly to the *Recruitment and Retention* recommendation from the Cybersecurity Education Workshop report [1].

The specific games included in our analysis were chosen based on a combination of keyword searches on the Web, recommendations from cybersecurity professionals, and personal experience, and the games are listed in Table I. Although we focused on games designed explicitly to teach cybersecurity, we also selected other games that include cybersecurity themes: in particular, *Bioshock*, *Shadowrun Returns*, and two entries from the *Deus Ex* franchise were selected for their inclusion of “hacking” experiences. *Android: Netrunner* and *Control-Alt-Hack* were chosen as analog games based on cybersecurity themes, the latter having been designed as a teaching tool. *Capture the Flag* is one of many eponymous games in which teams of

programmers simultaneously secure their own servers while hacking opposing teams’ in a time-limited competition; we selected the implementation from Buena Vista University due to our ability to informally interview a team coach. We were unable to obtain research access to *NetWars* (SANS) and *CyberNEXS* [16] (Leidos), two commercial cybersecurity games. The evaluation of *CyberProtect* [29] was limited to analysis of a descriptive gameplay video, not first-hand experience.

These games we analyzed were designed for a wide range of target audiences. Some are clearly designed for young children and focus on encouraging simple safe online habits, whereas games such as *Capture the Flag* require specialized programming knowledge in order to minimally participate.

IV. FINDINGS

Table I lists the games and provides a summary of our assessment, using a three-tier model described below. All of the games included cybersecurity content (Q1): as mentioned above, this was a criteria for their selection, although the nature of this inclusion varied. At one extreme, *CyberCIEGE* provides a simulation of a company with multiple networked computers, digital assets such as databases, workers who need training, policies that require enforcement, physical security, and technical components such as access control lists and password strength requirements [14]. At the other extreme is *Gem Jam!*, which starts with a static screen of online gaming tips and then proceeds as a *Bejeweled* (PopCap) clone with no other mention of cybersecurity content.

It is the investigation of our second research question— whether the game mechanics support the learning objectives— that led to our three-tier model indicated in Table I. These three tiers are:

- Type 1 Games that convey cybersecurity concepts through narrative and/or theme only. There is no representation of the concepts within actual gameplay. That is, the act of playing the game does not require any decision-making that would reflect an understanding of cybersecurity concepts.
- Type 2 Games that integrate multiple-choice questions (including yes/no options and

branching narratives) that correspond to cybersecurity concepts. Answering these prompts correctly requires an understanding of the concepts.

- Type 3 Games that require ambiguous decision-making such that making good decisions implies an understanding of cybersecurity concepts.

Type 1 Games

Type 1 games show minimal learning potential through gameplay: cybersecurity concepts are only present in narrative, but not through players' decision-making processes. The suite of games produced by the National Center for Missing &

Exploited Children exemplifies this category. In *Stop That Post*, for example, the player is told that friends or family are going to post something embarrassing online, and that they must race to stop them. The player then plays a 2D physics-based platformer, and if successful, they receive narrative feedback that the social media post was prevented. Playing the platform game has nothing to do with cybersecurity content: one could easily click through the narrative, enjoy the game, and emerge none the wiser about safe online habits. The games we classify as Type 1 exemplify the phenomenon of narrative as a feedback mechanism, not a mechanism [30]; furthermore, they fail to

capture the essential desired learning outcomes into gameplay, as best practices dictate [18].

This is not to say that these games have no value. Most of the games in this category were designed for young players, and the games are part of a rich ecology of content designed around themes of safe online habits. While the games may not teach through gameplay, they serve as incentive to bring young people to the site, where they can find other tips, videos, and activities that reinforce these ideas. This use of games-as-marketing is common in the commercial sector, and it is uplifting to see a beneficial organization such as the National Center for Missing & Exploited Children using it for positive social impact.

Control-Alt-Hack presents an interesting case for analysis. It is a game in which the players are white-hat hackers competing to become CEO of a security company [31]. The game is a re-themed version of Steve Jackson Games' *NinjaBurger*, in which the players are ninja fast-food delivery agents who are competing to take over the franchise. The mechanisms of the game are identical: the player accomplishes missions by rolling dice and comparing the results to various skills. The five skills in *NinjaBurger* are combat, stealth, disguise, climbing, and customer service; these become hardware hacking, software wizardry, network ninja, social engineering, and cryptanalysis in *Control-Alt-Hack*. In either case, the gameplay does

| Title | Developer or Publisher | Type | Pedagogic Intent |
|-------------------------------------|--|------|------------------|
| <i>Control-Alt-Hack</i> | University of Washington | 1 | yes |
| <i>Cyberbully Zombies Attack!</i> | National Center for Missing & Exploited Children | 1 | yes |
| <i>Gem Jam!</i> | National Center for Missing & Exploited Children | 1 | yes |
| <i>Inbox Defender</i> | National Center for Missing & Exploited Children | 1 | yes |
| <i>Password Plunder</i> | National Center for Missing & Exploited Children | 1 | yes |
| <i>Stop That Post</i> | National Center for Missing & Exploited Children | 1 | yes |
| <i>Tad's Profile Panic</i> | National Center for Missing & Exploited Children | 1 | yes |
| <i>Bioshock</i> | 2K Boston / 2K Australia | 1 | no |
| <i>Deus Ex</i> | Ion Storm | 1 | no |
| <i>Shadowrun Returns</i> | Harebrained Schemes | 1 | no |
| <i>Cybersecure</i> | HealthIT.gov | 2 | yes |
| <i>Growing an Online Reputation</i> | Carnegie Mellon University | 2 | yes |
| <i>Mission: Laptop Security</i> | OnGuardOnline.gov | 2 | yes |
| <i>Phishing Scams</i> | OnGuardOnline.gov | 2 | yes |
| <i>Safe Online Surfing</i> | FBI | 2 | yes |
| <i>Capture the Flag</i> | Buena Vista University | 3 | yes |
| <i>picoCTF</i> | Plaid Parliament of Pwning and Team Daedalus | 3 | yes |
| <i>CyberCIEGE</i> | Naval Postgraduate School | 3 | yes |
| <i>CyberProtect</i> | Carney, Inc. | 3 | yes |
| <i>Cybersecurity Lab</i> | NOVA Labs | 3 | yes |
| <i>Android: Netrunner</i> | Fantasy Flight Games | 3 | no |
| <i>Deus Ex: Human Revolution</i> | Eidos Montreal | 3 | no |

Table 1: Summary of Game Analysis

not involve stealth, disguise, software wizardry, or cryptanalysis: the player rolls dice and compares them to a skill's numeric value. To claim that *Control-Alt-Hack* teaches about cybersecurity, then, is an equivalent claim that *NinjaBurger* teaches about ninjitsu and fast food. Both games incorporate tactical risk management, but this is not tied intrinsically to their content domain. Without empirical data or established theoretical models of educational game design, claims about what the game teaches are unfounded. By contrast, consider TiltFactor Labs' *Buffalo*, a card game designed to overcome personal biases, which was designed following best practices of transformative game design, and which has been shown to have significant cognitive effects [32].

Given that Type 1 games do not incorporate key concepts into the gameplay, but we have already established that all games teach something, there is a possibility that these games are working against their stated goals. In the absence of evidence or models, we are left with the distinct possibility that playing one of these games may cause the player to build inaccurate mental models about cybersecurity. For example, the dice-based risk management of *Control-Alt-Hack* could result in a player thinking that online risks are worth taking, or *Stop that Post* may make the player believe that they can remotely police their friends' and families' social media habits.

Type 2 Games

The emergence of this classification came from the observation that many of these "games" are essentially interactive digital quizzes. That is, the gameplay consists of viewing prompts and selecting from a list of options; these are *puzzles* in Burgun's taxonomy [25] since they have pre-ordained best solutions. Just like any other multiple choice exam, such games could be used as assessments of learning, but only if the constructed items are reliable and valid. These games can also be used as self-paced replacements for traditional educational interventions. They certainly don't capture the essence of "finding the game in the content." Although a cybersecurity professional does frequently read and make decisions, these decisions are rarely as constrained as two to four options in a game.

A strength of games in this category lies in their ability to teach through narrative. Games such as *Mission:*

Laptop Security tell an interesting story about a protagonist spy who previously lost a laptop and now is subject to institutional oversight; the choices in *Cybersecure* are based on realistic and compelling scenarios from health information technology. These are not teaching through gameplay, in the sense we have approached it, but through narrative; a story-based learning evaluation model is more appropriate to apply than a games oriented one.

As a clarification, note that *Safe Online Surfing*—which we classified as Type 2—is actually a suite of games targeting U.S. grades 3–8. Each grade level includes eight minigames. Some of these fit into our Type 2 classification, while others are Type 1: they are cybersecurity-themed minigames where the core gameplay has no relationship to the content. We have classified the entire suite as Type 2 since they are offered as one product.

Type 3 Games

Type 3 captures *game* in the sense defined by Burgun [25]: a competition that involves endogenously meaningful ambiguous decision-making. These are not puzzles with single solutions, and hence, they represent opportunities for extended learning through repeated play.

The most illustrative example is *Cybersecurity Lab*, which takes three minigames and threads them together into a compelling cybersecurity narrative. The three minigames are designed around authentic, though abstract, cybersecurity learning objectives. One is a scaffolded series of puzzles in which the player must make strong passwords and guess an opponent's; the player can observe that the opponent can more easily guess simpler passwords as compared to more complex one. A second minigame involves identifying phishing scams by comparing real and fraudulent communications (within the fictional world). The third minigame develops computational thinking skills [33] by using a blocks programming language— as in *Scratch* [34] and *App Inventor* [35]—to program solutions to mazes. These minigames clearly make the content into a game and represent good practices for educational game design [18]. Furthermore, they are embedded into a Web context that includes additional media to explain careers in cybersecurity. Like the Type 1 games, *Cybersecurity Lab* provides an engaging play experience

that brings players to an informational portal, but more impressively, the game itself manifests good design principles.

Whereas *Cybersecurity Lab* is an abstraction of cybersecurity concepts appropriate for younger children, *CyberCIEGE* exemplifies the opportunities in a simulation game. As mentioned above, *CyberCIEGE* involves making tactical decisions about financial allocation, with options including hardware acquisition, network configuration, personnel training, policy enforcement, and physical security. These are relevant decisions for cybersecurity content, albeit in a fictionalized environment.

A weakness of *CyberCIEGE*, *Cybersecurity Lab*, and others is that the player decisions are against discrete, algorithmic opponents: that is, each of these is really an elaborate puzzle that has a best solution [25]. By contrast, *Capture the Flag* has players directly engaged in real cybersecurity challenges against opposing teams. They must work together to identify vulnerabilities and protect against them, and when making offensive moves, they try to circumvent the protections installed by opponents. The technical elements of cybersecurity content are deeply embedded in this game, but it comes with a high price of admission: players must already be competent computer programmers and savvy with computer system operation. While this population is prime for recruitment into cybersecurity careers, targeting them does little to improve the overall pipeline, much less issues such as diversity [2].

It is important to consider what players can learn from the games that are not designed to teach cybersecurity. In the original *Deus Ex*, “hacking” was merely a matter of spending the right resources and having limited time to gather information from computer consoles. The subsequent *Deus Ex: Human Revolution* revised this to a minigame involving connecting to multiple servers across a network topology without being traced. The first is a poor abstraction of cybersecurity, while the latter includes some relevant game mechanics and theme. *Shadowrun Returns* includes lengthy sequences in which characters plug into “the Matrix” and enter a cyberpunk style virtual world of avatars battling intruder countermeasures. The Matrix levels follow a similar geography to the non-Matrix levels, and it still essentially a strategic combat simulator of ranged and melee combat: the character attributes and abilities are

different, but the fundamental mechanics are those of tactical turn-based combat, which do not significantly represent cybersecurity fundamentals. *Android: Netrunner* also features a dystopian cyberpunk theme, but it is more coherently situated within authentic cybersecurity themes. It is an asymmetric game, with one player taking the role of the corporations and the other, the “runner”; the corporation wins by advancing agendas that are hidden across servers, while the runner wins by stealing these agendas through hacking. That is, the mechanics involve secret information, defenses against unpredictable attackers, and different goals for each side, all of these being authentic cybersecurity topics. Of course, elements of this game also violate reality: we have no countermeasures that literally fry the brains of opposing hackers. Further study is necessary to determine what people learn about cybersecurity by playing these games—both accurate and inaccurate learning—and this points again to the value of post-play debriefing as a means for helping players form useful mental models [22]–[24].

Realism Vs. Dehumanism

Many of the children’s games included cyberbullies as a narrative element, and these were consistently portrayed as subhuman or nonhuman. *CyberBully Zombie Attack!* is a tower defense game in which the player defends a school from “cyberbully zombies.” *Safe Online Surfing* includes a challenge against a cyberbully pirate crab who needs to be stopped before he sends a mean email. This design decision has a distinct othering effect. By portraying cyberbullies as something inhuman and evil, it fails to reflect the reality that there is someone else on the other side of the computer with their own motives and story, simultaneously a more difficult and more important reality to portray. We are concerned that this may be insulting to those students who have dealt with the harsh realities of cyberbullying, as indicated by some of our informal interviews.

Other games portray the conflict between opposing sides more evenly. *Android: Netrunner* presents a fictional world with two playable sides: that of a corporation and that of hacker. *Netrunner* creates a unique set of motives and objectives for each side and thus humanizes each position, albeit within a cyberpunk aesthetic. Despite the fictional theme, the

game narrative captures the notion that the corporations have information that they must secure in clever ways, and they must do so purely through predictive defenses, while solitary individuals with a network connection can potentially break in and steal sensitive information. *Capture the Flag* takes a different approach: all of the teams are engaged in a friendly competition, and each is taking both offensive and defensive maneuvers. By doing so, the players learn how to harden systems and how to think like attackers; the unstated assumption is that the players will use this knowledge for social good and not for criminal or nefarious purposes. These games foster a richness of perspective that relates to nongame reality, rather than simple demonization of the enemy. As Koster [9] describes, demonization of the enemy may be a common game storytelling technique, but it does not represent 21st-century values.

V. Conclusions and Future Work

Evaluating cybersecurity education games based on their design characteristics produced a three-tier taxonomy. We observe significant variability among the games regarding the integration of cybersecurity education learning objectives into gameplay mechanisms, and the literature suggests that those with better integration should produce better learning outcomes. However, we discovered no empirical assessments of any of these projects, and very few articles explaining, contextualizing, or justifying their designs. This is problematic for cybersecurity education, and we are concerned that federally funded projects are not producing appropriate scholarship to advance the field. Not only does the community not know which techniques are efficacious for what purposes, but we also do not know if the games themselves are producing learning outcomes contrary to their stated goals.

Our analysis demonstrates the value of investigating both digital and non-digital games, as well as those not

designed for pedagogic purposes. Such games can produce authentic learning outcomes, and many of those we evaluated have much further reach than any of the digital, pedagogically-designed games. These can be combined with educational interventions such as inquiry-based investigations and debriefing sessions to help learners contextualize what they have learned and transfer it to other situations.

There is an opportunity to create games based around careers and educational paths toward careers in cybersecurity. This relates to a specific recommendation from the Cybersecurity Education Workshop [1]. Although some existing games address these issues with ancillary content such as collocated videos and text, these are not addressed directly in any of the games we reviewed. It is not the goal of this work to provide requirements for specific educational game designs, but rather a useful lens through which to consider the designs themselves. The requirements for individual games will depend on context specific factors such as the intended audience, environment of play, and development budget.

The games with the most authentic portrayal of cybersecurity content are also those with the highest barriers to entry. That is, there are broadly accessible games with little or no mechanisms for teaching cybersecurity concepts, and there are simulation games that require specialized understanding of technical skills or understanding of information systems and their management. *Cybersecurity Lab* is the only game we reviewed that seems to scaffold a learner between these two levels, and so we believe there is an opportunity here as well for new projects and initiatives.

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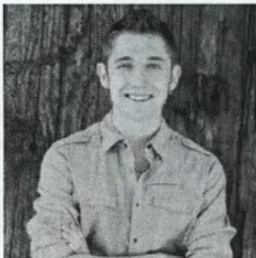
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Author Biography



Paul Gestwicki is an Associate Professor in the Computer Science Department at Ball State University. He teaches

multidisciplinary undergraduate teams in an academic studio, mentoring them in the creation of original educational video games.



Kaleb Stumbaugh is an undergraduate research assistant at Ball State University. He is majoring in

Computer Science.

Appendix B: *The Social Startup Game*

Key Concepts

- *Player*: the person playing the game, there is only one
- *Company*: the entity that the player works for
 - *Exposure*: the chance of gaining another exploit
 - *Users*: the indication of score
 - *Users Over Time*: the amount of users generated per in game hour
- *Employee*: assignable entity
 - *Skill*: ability to perform a task; the higher the skill, the better the employee is at doing that task
 - *Development Skill*: related to the development task
 - *Maintenance Skill*: related to the maintenance task
 - *Task*: the continuous action of an employee
 - *Development*: advance the completion percentage of the feature in development
 - *Maintenance*: lower the exposure of the company; advance percentage of completion towards fixing an exploit
 - *Special Task*: a task specific to a narrative event; during the finite time period over which this task takes place, the employee is not available to perform any other task
 - *Background*: the employee's educational background and interests. This does not affect employee skills.
- *Exploit*: an object that drains a small percentage of the company's total users until it is "fixed"
- *Feature*: an object with a "users over time" attribute that, upon completion, adds to the company's total users over time value and increases the company exposure by a fixed amount
- *Narrative Event*: the driving narrative devices: the player is presented with situations and have to decide how to respond from a given list of options
- *Introduction*: the screens where the player learns about the goal and narrative frame; these four screens show before the main play screen
- *Tutorial*: the first event that occurs; it is designed to tell the player what their basic actions are and how to navigate the U
- *Conclusion*: the game summary shown after the time limit has been hit; tells the player if they won or lost, and why

Game Goal

- Win Conditions, tested at end of game time:
 - Greater than 50000 users
 - Less than 15% exposure

Playing the game

- Game time begins after the tutorial is completed or skipped. Game time runs for a total of 78 real time seconds. This is derived from the number of days the game covers and the speed at which hours fun.
- Day time hours run at one in game hour per real time second.
- Night time hours run at two in game hours per real time second.
- The player assigns and manages the tasks that their three employees perform.

- As an employee performs a task, their skill in that task increases, thus making them better at performing that task.
- When an event occurs, game time stops
- Event time and order are randomized.
- When an event is triggered, the player must decide how to respond to that event.
- Follow up events describe the results of the player's decisions (still pauses game time)
- After game time is up, the conclusion screen is shown which display a table of the company stats and the following text:
 - If both win conditions were met:
 - "We needed 50000 users and less than 15% exposure. You made some great choices! I look forward to working with you!"
 - If the exposure wasn't low enough but they had enough users:
 - "We needed 50000 users and less than 15% exposure. You neglected your duties as a security professional."
 - If there weren't enough users but the exposure was below 15%:
 - "We needed 50000 users and less than 15% exposure. You did well with security, but stopped us from gaining more users."
 - If neither win condition was met:
 - "Not only did we have fewer than 50000 users, but our exposure was above 15%! Your decisions were awful. You're fired."

Appendix C: Character in *The Social Startup*



Abdullah Nasr

Bachelors in Electrical Engineering, Iowa State University
Abdullah used to work for a larger social media company, but he prefers the excitement of a small startup.



Bruce Powers

Bachelors in Computer Science, Ball State University
Bruce was recently married and enjoys going to the gym and watching documentaries about history.



Esteban Cortez

Bachelors in Computer Science, Ball State University
Esteban worked in a factory until he was 33, then he went to college and decided to get involved in software development.



Ivar Johansen

Bachelors in Chemistry, Stockholm University
Masters in Electrical Engineering, Uppsala University Ivar teaches kids how to build simple robots as a volunteer in a local school.



Janine Palmer

Bachelors in Computer Science, Virginia Tech
Janine is especially talented at meeting with customers and understanding what they want from a product.



Jerry Chen

Bachelors in Computer Science, University of Hong Kong
Jerry interned at a local company in high school and has been working as a software developer ever since.



Melissa Barnard

Bachelors in Mathematics, Stanford University Melissa has always loved games and puzzles, but she especially loves bicycling and walking her German Shepherd.

Nancy Stevens

Bachelors in English, Georgetown University
Masters in Computer Security, Purdue University Nancy has a popular podcast about being a woman in technology.



Vani Mishra

Bachelors in Computer Engineering, Indian Institute of Science
Masters in Software Engineering, Ball State University
Vani was born in India and came to the United States for graduate school. She loves music, dancing, and PHP.

Frieda

Frieda is the administrative coordinator at Social Jam.



Appendix D: Semi Structured Interview Protocol

Prior to playing the game:

1. What is your favorite subject in school?
2. What is your favorite app?
3. Who are the people who make [favorite app]?
 - a. What does that person look like? (This may be a leading question)
 - b. Did they go to college/what did they study?
 - c. What were their favorite subjects in school?

After playing the game

1. Did anything surprise you?
2. What kinds of decisions did you have to make in this game? how did you make the decisions?
3. Where do apps come from?
4. Do you think you could get a job making aps? Why or why not?
5. How does someone get a job making apps?
6. Do you have any questions?

Appendix E: Second Phase Codes

academics: computer science
academics: science-engineering
academics: dislike

apps: communication
apps: games
apps: productivity
apps: for phones
apps: creative
apps: music

characters: pragmatic
characters: empathic

culture: male domination
culture: smart people look different

developers-like: math
developers-like: english
developers-like: art + stem
developers-like: technology
developers-like: science
developers-like: art
developers-like: design
developers-like: programming
developers-like: animation
developers-like: fundamentals
developers-like: computer science
developers-like: engineering

developers: not considered
developers: smart
developers: work hard
developers: crazy

developer-appearance: artists
developer-appearance: nonconformist
developer-appearance: geeky
developer-appearance: young
developer-appearance: smart and techy
developer-appearance: normal

development: difficulty
development: scale
development: coding
development: teams
development: testing
development: time
development: design separate from programming

development: entrepreneurship
development: anybody can do it

distribution: distinction of sources
distribution: companies as gatekeepers
distribution: appstore

economy: demand for apps
economy: jobs education: degree has value

education: degree not necessary
education: degree as career
education: development classes
education: online resources
education: multiple paths

experience: scratch
experience: school
experience: code.org
experience: gamesalad

self-efficacy: technology requisite

game design: role-playing
game design: one right answer
game design: genre preferences
game design: empathy
game design: strategy

interest: problem-solving
interest: Minecraft
interest: creativity
interest: english
interest: science
interest: math
interest: writing
interest: terraria
interest: art
interest: band
interest: sketchbook pro
interest: history
interest: facebook
interest: wattpad
interest: gym
interest: clash of clans

learning: working hard
learning: improvement
learning: feedback loops

ssg: usability
ssg: vocabulary
ssg: math

security: disclosure
security: hackers
security: piracy
security: responsibility
security: pragmatism
security: encryption
security: confidentiality
security: number of exploits
security: strong passwords

Appendix F: Categories

Computer science as the domain for app development

Character-based decisions

Academic vs non-academic learning

Incremental vs Entity theory of intelligence

Varied perspectives on developer appearance

Development is difficult

Companies as gatekeepers

Democracy of development

Economics and development

Degree as career

Positive educational experiences with coding

There is one right answer

Learning through practice

SSG issues

Surprise at hackers

Responsible disclosure

Protecting personal information

“App” means “game”

Appendix G: Interview Transcripts

The following are the transcripts of the semi structured interview policy. The transcriptions are include both the subject's and the interviewers statements, usually interleaved. Vertical space indicates a pause, such as playing the game.

Subject 1

What is your favorite subject in school?

Um..probably language arts

What's your favorite app?

Like, an app that you get or just one that's on your phone?

Any

Um, well, messaging, and then, that's about it

Who do you usually talk to when messaging---school friends?

Yeah

Remind me how old you are

Fourteen

[offtopic]

Tell me about how you imagine the people who make the messaging app that you like. Where do you think those come from?

Um [looks perplexed]

Let me start with a different question: when you think about the people who make those apps, what do they look like?

Um, kind of, anything, I guess

Do you ever think about what they might have studied in school or in college?

Technology things

What do you think their favorite subject in school would be?

Maybe like, I don't know, some kind of ... math, or language arts too

You started by saying math, and you added language arts, and to a lot of people those things are very different.

Yeah

Can you tell me why you think both of those?

Well, with like, the way it's designed, and the way you can communicate with other people

OK.

[Introduce the game]

Do you have any questions ..?

At the beginning it's a little hard to tell what to do.

Did anythign surprise you?

Um, not really

What kinds of decisions did you have to make?

Whether to kind of notify people about what happened or keep it secret.

And how did you make those decisions?

Um, I guess I just kind of went with what I thought would be a good idea to do if i was in that

position.

How do you know if it's a good idea or not?

Hm [shrug] cuz I don't have that kind of experience.

So what do you think about where apps come from?

I know that it usually takes a lot of people just to design little things, cuz in school in BIT last year we worked with a program called Scratch, and it was a lot harder than we thought to do stuff, to make like a bigger app or even like a little game

Can you tell me what BIT stands for?

Yeah I think it's Business In Technology but I'm not sure

Do you think you could get a job making apps?

[inaudible, but affirmative]

Lately that's what the world has been focusing on like social media, and apps and devices, and I guess there's just a lot of job opportunities for people to do that.

So how do you think somebody who makes apps gets that job?

Um, not sure, maybe would have some kind of like start-up program where you can show what you want to make to a company or what you want to do.

[Show her how to change tasks to employees]

Can you tell me about how you're making those decisions, about who's doing what?

Um, trying to make them equal for both sides [development & maintenance skill]

Can you tell me about why everyone is on maintenance now?

Um, cuz there's more of the, I'm not sure what that one is (dev't or maintenance skill)

[game ends]

Was anything different that time?

It was a little different because I didn't know I could switch between the maintenance and development

Did that affect how you made decisions at all?

Not really.

Subject 2

You're homeschooled, right?

Yeah.

Good, my kids are home schooled too. I don't know what kind of curriculum you follow, but can you tell me what your favorite kind of work is or what your favorite subject is...?

Science mostly

Science? What kinds of stuff do you do in science?

Experiments, learn about ... science, pretty much. Um... [asks mother] What science do we do Mom?

You answer!

I forget!

That's OK, tell me, how old are you?

I'm ten

Ten great.

[off topic]

So do you use any apps?

I use... for school? or just...

At all. anything, and do you have any favorites?

I like to make pretend videos, like when I'm playing games on my mom's iPad, so yeah.

How does that work?

I just act like I'm talking to the people, and I just say what I'm doing and how I'm doing it and what I'm going to be doing and how I'm going to do it.

And you record it on the iPad then?

Yeah.

Neat. So do you ever think about the people who make those apps? They had to come from somewhere, right?

Sometimes

What do you think they look like?

I don't know, really

Try to imagine, someone who makes those apps, can you picture what they might look like or where they might be?

Not really.

OK, can you think maybe what their favorite subjects in school were?

Huh. Maybe like Math, because you kind of have to know math to kind of develop the games and do all the coding and stuff.

OK, anything else?

Not really.

Do you know any coding?

A little bit.

What have you done?

Not really much. I've just like typed into my computer and like sometimes--most of the time nothing happened.

That's what happens to me too, and that's my job. It's hard!

[introduce game]

[Intro Ends]

So ...

[unintelligible] I just kind of...

[Shows how to click on the Alerts button]

[Demonstrate how to change task]

I can change all these guys too?

You bet

Can you tell me about what you're thinking while you're reading?

[reading screen] One of your engineers is 'connected' about, what does that say?

Injection

Injection attacks. If it's not handled correctly hackers may be able to run their programs on your machine. Who will you ... assign... to ... investigate.

What is our goal? [Points to status screen] "Progress towards goal"?

Um, I don't remember what the number was that Frieda said. I think it's 20,000 users. Or, it was the CEO at the beginning. I think it was 20,000 users. Progress tells you what percent you are.

Have you done percents in math?

Mmm mmm, not yet.

Oh, so that might be a little confusing

Do you know what a press release is?

No.

That's when you make a public statement about what happened, you tell everybody, "Here's what happened."

[Selects it]

So the goal is so many users?

Yes, you can see your percent is over 100 now, so you've met your goal, and you have a couple hours left before the end of the game---in-game hours

[end game]

Did anything in the game surprise you?

Like how there was _hackers_, how there was so many of them, and they were so big of a... so big of a problem to the game and stuff

And that was surprising to you?

A little bit

What do you think about the hackers?

...I don't really know.

Do you have any idea why they were attacking?

Maybe they wanted to call the game their own or something?

What kinds of decisions did you have to make in the game?

Like to see if we should tell the public or just keep it quiet about the hackers and... stuff.

I noticed when you had the option to send someone to the security conference, you sent Esteban.

Mmm hmm

Was there a reason you sent Esteban?

He's the guy [a bit cheekily stated]

When you had to investigate... I forget which attack it was, script kiddie attack maybe ... that time though you chose Janine to investigate the problems. Do you know why you chose Janine for that one?

No.

So, after playing the game do you have any thoughts about where apps come from?

Little bit.

Can you tell me about what you think that might be like?

Um,... it's like the people have to make them .. and then they have to... I'm confused. So, the apps, where they come from?

mmm hmm!

I don't really know, actually.

Do you think you could get a job making an app?

Probably not

Why is that?

I'm not that smart at making stuff when it comes to like games and stuff.

OK. [offtopic] Do you have any thoughts about how somebody would get a job making apps?

If they're like really smart and they know like how computers work and how devices work so they know what's the best idea and stuff.

Do you have any questions for me, about the game or the study?

Not really.

Subject 3

How old are you?

Twelve.

[offtopic]

What is your favorite subject when you're doing schoolwork?

probably reading

Why is that?

Just because I like the books that have a lot of, like, problems, but then they find out what the problem is and fix the problem.

Great. What is your favorite app?

I don't really have a favorite app but I do like Minecraft a lot.

What do you like about Minecraft?

I can build houses and like other buildings and stuff

Have you ever seen any pictures of notch, the guy who made minecraft.

If you imagine... Minecraft was created by a guy named notch, that's his nickname, what's his real name? Marcus Persson I think is his real name. but, now it's worked on by many many people. Can you imagine the people who make minecraft, what they might look like?

Mmm no not really

Can you imagine what kinds of things they would have liked in school?

Science, math [inaudible]

Why do you think science and math

Math because you need to know math to do like, stuff, for the game, and science because it will help you put stuff together [raises hands like slotting pieces together] to control the game, I guess

That's a good answer, that's fine. The people who made minecraft, do you think they went to college and can you imagine what they might have studied in college?

No, I don't think so.

It's a long ways away when you're twelve.

Yes

So, do you want to try our game?

Sure

[introduce the game]

OK, so, how do I figure out what to do?

Start by clicking on the blinking alerts button

do I press this? (employee area)

Sure.

[Explain the task assignment]

So I can like, press on there? (task assignment)

Mmm Hmm

[Brief talking over each other, confirming that she can use the task assignment buttons on other characters too]

What is 'maintenance'?

THat's a good question. Maintenance is keeping the current systems up and running, making sure everything is working OK, and then development is making new features.

OK, now, do I press this again?

MmmHmm

OK, so, ...

What were you going to say?

I was just going to ask you what I should do next, but ... should I change their jobs again?

You're welcome to do that, mm hmm

What does 'press release' mean? [Reads it emphasizing verb meaning of 'press']

A press release is when the company goes to the public and says, here's what's currently happening, they would tell everybody that there's a problem.

Ummm

Can you tell me about why you're making those changes?

Just to see how they work better on the... [inaudible, probably implying 'other tasks']

What does 'development' mean again?

Development is working on new features for the program

What does 'train staff' mean? [in the password event]

So you could teach your staff to use better passwords.

[selects it]

[game ends]

Did anything surprise you in the game?

"Mm, probably how like the hackers and like the passwords and stuff. How there are hackers trying to get people's information, and how we lost people just because of [them?]

[Note that 'hackers' was a similar answer to 368.2, whose interview she was in the room for]"

Can you say anything more about why that surprised you?

mmmm I don't really know like...

It's OK. What kinds of decisions did you have to make in the game?

Figure out which people would be the best people to fix the problem and like doing something about it, not just ignoring it.

And how did you make those decisions? How did you decide who to send?

Just by what their jobs were, like

What do you mean, when you opened them up and looked at their backgrounds?

Yeah

I noticed that when you had an option to send someone to the security confernece, you sent Nancy. Do you remember why you chose Nancy?

No, not really

And when you were looking at the injection attacks, you looked over the people and you sent Vani, the one on top

just because like she was a computer person and she liked to that kind of stuff.

At one point, one of the characters brought their daughter to work if she wants to make apps, and you chose Computer Science. You looked over the list for a while [which was not exactly true], do you remember why you chose computer science?

Just because you can make like apps on the computer and figure out how the stuff works

Can you tell me where you think apps in general come from?

mmmm

We talked about Minecraft earlier, if you think about in general, where do apps come from?

Probably from the people who make them, there's a whole bunch, people who made them, so, yeah

What kind of people do you imagine--can you tell me about these people?

Really smart and like really good at doing their job and working on computer stuff

Do you think that you could get a job making apps?

Ummmm. no. Probably not.

Why's that?

Just because I don't really like, think, about it a lot, and ... yeah.

OK. How do you think somebody would get that job?

Studying really hard probably

Do you have any questions about anything you saw, or any questions about the project or the study?

No.

Subject 4

What is your favorite subject in school?

Um, English, like, writing.

What do you like about it?

I like creative writing and being, like, imaginative

[offtopic]

What is your favorite computer app?

Probably like planner and calendar apps, like, organizing, so I know what's coming

Have you ever thought about the people who make those apps--the calendar and planning apps--have you thought about where they come from?

Kind of, because actually my teacher had us testing, she made an app which was a planner app such that she tested us with it. So after that I kind of did, but that was this year, but before that, not really.

[offtopic]

If you imagine the people that make apps, can you tell me what you think they look like?

Well, I'm pretty sure like people, they're like artists and stuff, like ... looks, I never really thought about that. [long pause] I picture like the people who _design_ it would be kind of like artists, kind of, messy kind of regular people, and the people who publish it would be kind of like, official, ... I don't know, yeah.

So these people who work on the apps, what do you think that they studied in college?
um...

You already mentioned there's kind of an art and design side, and a business side.

Yeah, yeah, um, art and design, and then, like, technology, if there's, like, a video game

And if you think about those same people, who make these apps, what subject do you think they liked in school?

Art... or technology

[introduce game]

"[on first page of intro]

OK, what do I, .. do I click?"

[affirm]

"[on second page of intro]

[chuckle]"

"[on third page of intro, gesturing to word ""system""]

What's this, like, your computer system?"

Yeah, the Social Jam product that they're making

[affirm]

[game start]

So do I, I'm not really sure what to do
[explain to click on alerts]

[explain task changing and clicking on faces]

Ok

Should I click on one of these here?

Sure, just before you do this event, keep in mind that you can click on these to change their tasks, too.

OK

So, are these other ones you can...

You can click on any of them

Oh

I'm not quite sure what [inaudible]

The indicator here tells you what their main job is
right

Vani is maintaining the system, keeping it secure, and Nancy is developing new features

Yeah... oh, OK, I got it

Can you tell me about how you're trying to make this decision?

I'm looking at what she studied, .. [inaudible], so what she wants to get um a job in and then like what the choices are.

[inaudible muttering to self about the options]

So how do we fix these [the exploits], is that what the alerts are?

By having people on the maintenance skill, they will be working on this.

OK

The maintenance task, I mean

Yeah

Do you want me to explain my reasoning?

Yeah yeah

OK, so, since the attack wasn't successful, and we need our people, [trails off]

Ok

[points out grammatic error in message]

[pointing to option to training employees in good passwords] Since we want to get better, so if the problem comes up again

[Indicating skill levels] So is this like how much they've done of these? Like, the numbers?

That's actually their skill at that, so how good they are at the task

Oh OK
[inaudible]

Do you know what a press release is?
No
[explains it]

Whats the line?
That's your goal.
Oh!

[clicks through the end screen]
That was the end of the game.
Oh!
It was the success screen, since you were able to meet your goals.

[mute music]

Did anything in the game surprise you?
Um, it surprised me that I was able to get to the goal.

Can you tell me why that surprised you?

I was expecting it to be um ... more ... i don't know [inaudible] I expected I'd have to teach more, the other people on there, um, more about [inaudible] because there's only like two or three, so that surprised me

Anything else surprise you?
[negative]

Can you tell me about what kinds of decisions you made during the game, the kinds of decisions you made and you how made them?

um, I... had to... decide whether to just let it go because it wasn't like a big deal or smaller than other problems or to um... ah ... there was some where you had to pick which of the workers would fit best with each thing, and ...

I noticed when you had those kind of choices, you went in and looked at their bios. Do you remember what you were looking for, or how that helped you make a decision---or maybe didn't help you make a decision?

It helped me make a decision by telling me what they majored in, uh, what they were specialized in, and then just like how their personality is, like, the first one, I don't remember Janine

Yeah, she how she was more at communicating [inaudible] other people, making them feel good, then other ones like the second one would more good at like designing and creative kind of things, and the last one was better at like fixing [inaudible] technology problems

mm hmm

So that just let me know, like if um they needed somebody to, like one of them with the hacker, they needed somebody to fix it, so I sent the last one because she was good at fixing that kind of thing. So, it just let me know which one would be best for each job.

Do you think you could get a job making apps?

Um, depending on what kind of app, if it was like a game, I probably wouldn't be very good at that, but if it was um..

Why do you say that?

I'm not usually on technology, um, usually like that, but like if there was like a coloring app or an artistic one or like a planner like I said at the beginning, I would probably be able to do that more designing. I would be better at that than [trails off]

OK, so when we imagine people who make apps, how do you imagine those people got their jobs?

Um, probably their teachers saw their ability to do something like that in an earlier stage, so then they were able to get the classes in like high school and through college to be able to get better at that

So, if a teacher saw that somebody had potential and guided them toward a path that ended up with them getting a job in a company like Social Jam, here in the game, what can you imagine that they would study in college or high school, what kinds of courses would they take? What kinds of work would they do?

I think I did, yeah, the art, and technology

Do you have any questions about anything that you saw, or about the study?

The music, it was good to have a background thing, but like it was a little bit distracting because I was trying to, like, read them. I'm not very good at, like, I always have to go back when I read anyways, but um, and...

There was a way to mute it, too, or we could have turned it down. I'm sorry. I didn't notice it was causing a problem for you. I have heard the song so many times that I have tuned it out.

... The bios were helpful to make decisions, like that, and yeah.

Subject 5

What is your favorite subject when you're doing schoolwork

Maybe math.

Why's that

Just because it's fun to solve problems, Because I'm a problem solver, and because I like to know why it works, not just how it works.

What is your favorite app?

I don't have one because I don't really use iPhones or anything like that

What about laptop or desktop computers, do you do any work on those?

Yes. Probably Windows, PC.

What's your favorite kind of thing to do on Windows--what kind of programs do you run on it?

I don't know... Age of Empires is a game that is a CD, stick it in the computer, but most of that I use for like schoolwork and stuff

You do some school work on the computer?

Yeah

Do you ever think about the people who make those programs

Sometimes

What do you think they look like?

I don't think about what they look like, I just think about how hard it would have been, and how long it would have taken, and how many people it would have taken.

How many people do you think it takes?

ha, a lot, over a long period of time

Well, what makes you think that---what makes you think it would be very hard?

Well, at least for Age of Empires, because it is, there is a bunch of like a whole lot of editing and like the, you know what the game Age of Empires is?

Yes

Well, just cause it's like, there's a lot of different things, and you have to make all the commands do the things, and stuff.

Do you have any experience with programming or making your own programs---coding?

Yeah, somewhat.

What kind of stuff have you done?

Well, I've done the Google's Code.org, and I've done some of GameSalad, some stuff on GameSalad Creator.

Great. My son uses one called GameMaker which is a nice program too

Is it free?

"Yeah, there's a free one, and uh we're going to start using another one soon called Construct 2 which a student had recommended to me, so I'm going to check it out.

So, when you think about these people who make these apps, whether they're making things to help people do schoolwork, or... instead of 'apps' let me just say 'programs', people are making Age of Empires or people are making programs you use to help you do your schoolwork, what do you think they studied in school?"

pffffooo. Lots of stuff. Animation, first off for a lot of them, and programming, and stuff. Like, and they would math and stuff.

OK, anything else?

uh, well, all the basics, well everybody does, for the most part.

Well the beauty of being homeschooled is that you get to define what the basics are, so what do you think the basics are?

That's true.

That's why we homeschool too---we can define the basics for ourselves.

English, uh English, Math, Science, uh... well, we say Bible too, and then ... I feel like i'm missing one. I forget what it is.

OK. Want to try the game out?

[explain think aloud, and starting the game]

Do I click to...?

mm hmm

[end of intro]

I have to make the.. do stuff?

mm hmm

... so, what do I do?

You can start by clicking down here, on the alerts button

[explain how to change tasks and clicking faces to learn about workers]
[he goes through and reads about each worker]

"[has expanded bottom worker, so the main interaction area is not visible]
So then, I don't exactly understand what I'm supposed to do"
If you click on Melissa again, the other screen will come up, and she [Frieda] will tell you
OK

Do you know what a press release is?
mmmm no
[explains it]

[After sending one worker to deal with a different task, probably security conference]
Can you tell me why you switched them both to maintenance just now?
Ah, because the one is gone, so [inaudible]
OK

"[Looking at daughter advice screen]
Is it just one of them?"
You can only choose one, right. Can you tell me about how you're making your decision?
Um, because I think it would either be one of these two [CS and Graphic Design], because this [CS] would be more of programming and how to work the, and how to work the computers, and this [graphic design] would be more like the designy parts of it, so I think it could be either of these. Ah... let's just say... [clicks Computer Science]

"[He is looking over the event where 'report to police' is an option]
Can you tell me about the decision you're trying to make?"
Um, no, I don't really know. Um... don't really know, it's either one of these two [ignore/report], I think, but I don't know. ... Hmmm... I don't really know, so I think I need to say report to the police.

So, how do I make it go down?
The chart?
The, yeah
The chart actually is showing your, if you click on status you can take a look at it while the game's paused, this is showing how many users you have, so you actually want that to go up
OHH!
You want users up and you want exploits to be low.
I see. I see. I was, I thought that this [progress toward goal] was the one you had to keep below 15%.
Ah, no, the estimated exposure, if you click on status here [he does], it's the estimated exposure you want less than 15%. This one [progress toward goal] you want to go up.

The.... exposure... I see, OK, OK. I'm like, [adopts panicked voice] "Oh oh how do I make that go down?! Cause I just lost!" OK.

[talks to himself, inaudibly. he does this occasionally, often when reading on-screen text]

"[Facing the password event]

[laughs] Encrypt it [laughs] That's not one of the options. [laughs] Would this [train] be training to encrypt it, basically?"

Well, that's an interesting question. Encrypting is something you do on the server-side, to protect your data, but it's not something that guy... guy in advertising, something that they can do directly.

Right.

So, yeah, so those are the two choices that they give you.

Can I look them up and then get back to this?

What's that?

Can I look at them and then get back to this?

Yes, yes.

OK

What's PPH, or , PHP? [Vani's interest]

PHP is a programming language for making Web sites.

OK.

"[Looking at end game screen]

Are exploits and features good or bad, what are these?"

Features are good and produce users, but the exploits cost you users.

Mm kay.

[game ends]

When you played the game, did anything surprise you?

Well, it first, uh, where it's uh of the thing it says you just got attacked, whatever, and then, after that it wasn't really surprising, it was just like, OK, I got it, whatever

So you're saying---I want to make sure I understand---the first time you were attacked by hackers, you were surprised, and then after that you kind of expected them to attack some more.

Yeah, I tried to get ready for it, ... and then, uh, it's I actually kind of liked it, I liked the way you have to try and run your company, I just kind of like that type of thing. I don't know about other kids, but [trails off]

Sure. Anything else surprise you in the game?

... I don't think so

Can you tell me about what kinds of decisions you had to make while you played?

Whether or not to have somebody work on, like, whether or not to make things to create, uh,

send people to, uh, to get trained so that they're more effective, then whether or not to have some try to find the hackers, and whether or not to, uh, whether I thought I could handle it by myself or talk to the police or whatever

Do you remember when you were prompted, you had the option to send someone to a security conference, you sent Nancy. Do you remember why you sent Nancy?

Because she was the one that was, I don't remember what it was, because of when I was reading about the people

In their descriptions?

In their descriptions.

Sure. So do you think that you could get a job making apps?

Yes.

Why do you say that?

Um, well, if I'm, ... you mean me personally?

Yeah

Um, maybe, yes probably because I like to, uh, I can, ah, work on like programming stuff [inaudible] programming.

How does someone get a job making apps? How do you imagine they end up having that job? ummm, through an interview [chuckle]

What do you think leads to the interview---trace backwards from there

Well, somebody would hear about you, and uh, you probably need to get a degree, or be an entrepreneur and start your own app-making business

Mmhmm, "entrepreneur" is a big word for a twelve year old---that's a good word.

Antidisestablishmentarianism.

[both laugh] That's a good word too! Do you know anybody that's started their own business?

Well, me, my brother---well, me and then my older brother, the one who's not here, uh, [inaudible] friends, yeah.

And you started your own business

Yeah, it's, we, uh, got a little machine that takes pictures of old slides so that I can, people will send in a box or whatever of slides and I'll take pictures of them and convert them--or I'll take pictures of them and convert them to digital, and I'll give them a CD with them on it for 25 cents a slide

Great, that's cool

Do you have any questions for me or any questions about things that you saw?

Mmm not really, um, the one thing is, just at the very, at first, if I were playing the game, if I didn't have anybody here, at first, I wouldn't know what to do, because I saw the thing flashing, but I didn't know you were supposed to click on it.

Sure. There's some places where it's a little rough around the edges, it's not quite ready for public release, and that's one of the reasons we're bringing people to play it early.

Subject 6

What's your favorite subject in school

I'd say lunch but that probably doesn't count

I'll take lunch!

Sure.

Or you can list more than one, it doesn't have to be a single one.

I don't, I'm not a big fan of school

That's alright

I mean, I know I have to do it, but it's not very fun

Sure

What's your favorite app?

Favorite app...

or favorite computer program generally.

Uh... I don't know, I like Minecraft. It's fun.

What do you like about Minecraft.

I don't know, it's just fun, I'm creative so I like building stuff. So... I don't know.

So, if you think about a program like Minecraft---started by one guy, you probably know, and then now it's being worked on by a very large team of people

right

have you ever imagined those people that do that work, the people that work on minecraft?

Mm, well not necessarily Minecraft specifically, but I've thought about that kind of thing

What do you think they look like, the people that work on that?

I don't know. Probably, I don't know. Probably most of them are not American, probably a lot of them are from Japan, it's a Japanese company, isn't it? And then, I don't know. Probably just mostly that, just a bunch of geeky guys that sit at their computers and program Minecraft all day.

OK, and do you think they went to college and what do you think they studied?

It probably depends on what ones, and they probably studied, like, animation or, I don't know, something like that

And so these same people that you're imagining, what do you think their favorite school subjects would have been?

Probably art or math.

OK.

[introduce the game]

[finish intro]

[explain task changing, tap on faces to learn more about them]

[mumbles to himself while making some choices, but nothing clear]

Can you tell me about how you're making this decision?

I don't really know, I'll just kind of guess, I could report it to the police, or I could task someone to try to figure it out. I'll probably just task somebody to figure it out for now because, I don't really feel like getting mixed up with the police, so I'll task [someone] to do it.

OK, so I should not actually have had him do it.

Why do you say that?

Because he got a degree in electrical engineering and he got a degree in computer science, so...

[trails off] [tries changing the task]

Yeah, once he's on a special task he cannot be taken off of it.

I can't... OK

OK, tell Jerry to do it.

Hm, interesting

OK, so I have to figure out... how to fix the problem. Somehow.

Interesting, it's raising faster.

Oops, I should have sent...

What were you going to say?

I should have sent this guy.

Ok, so, that's the end?

That's the end

OK, cool.

Did anything in the game surprise you?

uh, yeah, a little bit. It kind of surprised me the random losing the customers because of the stuff popping up. So, then, I was kind of, like I didn't really know what I was doing, so I was trying to figure it out, and ... so then, it was like, I hadn't researched, I hadn't looked up who, I hadn't learned anything about my employees at the beginning, so I accidentally told the wrong guy to do something, uh

And that was, you said before, you thought it was the wrong guy because he had the electrical engineering degree instead of computer science?

I mean, he still got it done, but yeah, and then, yeah, I guess. So that was pretty much it.

When you had options to send people to the security conference, you sent Jerry, the guy at the bottom. Do you remember why you sent Jerry?

Yeah, I sent him just because he was uh he was one of the uh um computer science people. I figured he might be more helpful to, uh, computer science guys at a security conference.

Sure. And I noticed too when James from accounting brought his daughter to work, you looked over the options and you chose Computer Science there too. Do you remember why you chose that?

Uh, just because it seems like that's what, it seems like making an app would be more computers and that stuff than anything else.

OK, Tell me about where apps come from.

Anybody that makes them.

Can you say a little bit more?

So if somebody decides they want to make an app and they know, they sit down and do it. If

they don't know how, and they still want to do it, then depending on how complex the app is they either go to try to figure it out at some random source, or if it's a bigger, more complex project, they go take classes for it... and then they make the app.

Do you think that you could get a job making apps?

Probably, if I wanted to.

Why do you say that?

cause if I learned how to do stuff and then, I don't know, applied for jobs, especially if I got a degree, because people would be more likely to want someone with a degree in app development, or something along those lines

Do you have any questions about anything that you saw or any questions for me about the study.

[negative]

Subject 7

What's your favorite subject in school?

I like English and science

What do you like about those?

You get to be more creative than in other classes

What's your favorite app?

[perplexed]

Do you have a favorite app? Do you use any computer programs that you like?

Mmm, not really, I'm ... I've been trying to learn how to like develop games, but [trails off]

What kind of work have you done along those lines? Or what have you been reading?

I've been, I've read homestuck, and I've been inspired to make a webcomic that I don't have a name for yet, but I'm writing the script for it.

[offtopic homestuck]

Can you try to imagine the people who write computer software, who write apps. Can you imagine what they might look like?

[perplexed]

Or could you describe how you imagine they would look?

I imagine them to be like 17 to sort of early 20s in age, but appearancewise, I can't really [trails off]

Can you imagine what subjects they would like in school?

Probably English and Computers

Why do you say those?

Because in English, you get to learn how to develop characters and plot and stuff, and Computers, obviously, you learn how to deal with computers.

[introduce game]

[slide two, chuckles at the protect from hackers]

"You have three employees"--that's not a lot! [chuckle]

[explain task change and tap to learn about employees]

"[DDOS event]
Angry customer?!"

Can you tell me why you chose Jerry?
He seemed like with all, well, hold on, [opens his profile] "He worked for a local company in high school and has worked as a software developer ever since" so it seems like he would have the most experience and .. most, like .. willingness I guess.

"[looking at exploits screen]
[hushed shout]Fix it!"

"[Script kiddie event]
Just a script kiddie, so [trails off]"

[Spends some time looking at exploits list]

[angrily, hushed] Gosh, so many alerts.

[end] Yay!

Did anything surprise you while playing the game?
I think maybe the amount of exploits and all the choices, sort of, that you had to make.
And can you tell me why that was surprising to you?
That was, I mean, I know that starting up anything there's going to be some problems, but I didn't expect that many that quickly.
When you had the choice to have one of your employees investigate the injection attack--it was kind of toward the end of the game--you chose Jerry pretty quickly. Do you remember why you chose Jerry?
Yeah, well he seemed the most well-trained out of all of them, and the girl--I forget her name--she seemed more like someone who should be with, like, social, and not developer, but Jerry seemed like the better person for the job of that kind of thing.
How would you describe the decisions that you had to make in the game?
You really had to think of what sort of impact it would have later in the game when you would choose them, but you also had to make them kind of quickly, so... [trails off]
So how did you make those decisions? You mentioned thinking about future impact.
Thinking about how many people you could have lost, or how many people you can gain, from certain choices you take, so [trails off]
Do you think that you could get a job making apps, like at this company?
Yes.
Why do you say that?
... Like, it feels like, uh ... the way the company was going it was going on like strong and reliable and being able to tell users what's going on, so... [trails off]
I don't disagree that you could work there, I just wondered what you thought about it. So, how

does somebody get a job making apps?

They would have to learn how to code and script and stuff, and be able to like produce a game that people would play with it, and be able to develop a plot and a story, or whatever you needed for that game.... while still being semi-entertaining.

Do you have any questions about anything that you saw, or any questions about the study that we're doing?

[negative]

Subject 8

What is your favorite subject in school?

Math.

And what is your favorite app?

Tererria.

Oh thats cool! Great game. So who are the people who made Tererria?

Like...they have huge computers. Spend a lot of time working. Oh, and there have to be some super talented artists. The people probably went to college for like engineering.

You said engineering. What do you think their favorite subjects were when they were in school?

Uh...Probably science or math. Mainly that.

[introduce game]

[game play notes] He actually read all of the text. There were a lot of events from the get go so time took a long time to actually move (4 events in day 1).

[He took time to decide whether to do nothing or report to the police.]

How was it?

It was fun and different.

Was there anything that surprised you?

Yeah when the guy asked...I mean the guy's daughter asked about what she should study, I was surprised there wasn't the option to choose more than one thing.

Oh and what all would you have chosen?

Computer Science like I did. And engineering and math.

Ok that interesting. What kinds of decisions did you have to make?

Uhm...

Rather what were the choice you made and how did you make them?

I had to choose, like, the skill to have people on, and I used their degree. What they were best at. The other things I thought about what was good or what would get the most...points...Users.

Yeah users.

So again, where do app come from?

Code and computer programs. And I guess the people who write the codes. Computer scientists and engineers.

Do you think you could get a job making apps?

Yeah I do.

Why?

Well I've coded at my school at the beginning of the year and I was pretty good at it.

Oh so you've coded?

Well not really coded. It was like where we had to put things together...

So block coding?

Yeah, that!

What grade are you in?

Sixth.

That's very cool. So how does someone get a job making software?

Probably get a degree. Spend four years in college. And artists...would have to practice a lot.

Spend time getting better. And become tech savvy.

Ok. So lastly, do you have any questions for me?

No.

All right, thank you so much!

Subject 9

Ok so that's recording. So I'm just going to ask you a few questions to start out with. What's your favorite subject in school?

Uh...academic?

Yes.

I'd say English.

Ok and then just broad favorite subject in general?

Art. Or band. Either one.

Ok and that's visual art? So like drawing and painting.

Yes.

What's your favorite type of app?

Drawing.

So like you have...?

I like sketchbook pro. It's my favorite.

And then who are the type of people who make sketchbook pro?

Adobe I think.

And if you think about the actual people who made that?

The people? *pause* I don't know...

Ok yeah, that's a valid answer.

Yeah I've got no idea on that one.

So no idea like maybe what they would look like or what they studied in college if they went to college?

They probably went to college if they are making such a large app. And working for Adobe. They probably a crazy mad scientist. Like...Muahaha. We are gonna make this crazy app so people can draw.

Ok and then what...when those people were in school, what do you think their favorite subjects were?

Probably math and computer sciences...maybe art. Yeah.

Ok.

[Introduces Game]

[First Play Through]

The music is groovy.

Do you have what it takes? Yessss

Idk, I really like nancy. Soo I think I'm going to go with...oh Oh, what do? Oh, ok.

So she has a bachelors of english...oh my mom when to Georgetown! Nancy has a popular podcast about being a woman in technology. Oh thats cool!

Bruce has a... [reads text]

Ok lets see what Janine has for us. [Reads Text] Ok! I think I'm gonna go with Janine, because she sounds really cool.

So all three of them are your employees.

Yeeeahh I like them. They're cool.

Ok so status...features...oh selfie of the week!

[reads instructions]

[does not reassign anyone]

Ok. So. So we still don't have a selfie of the week!

Oh no, 55 users left....no! [notify users option response]

Oh. Oh no. You were attacked... [reads text] Oh *frantic* I'm going with! Ok. ok *frantic* uhm....especially talented at meting with customers...has a popular podcasts... and he...ok. I think I'm gonna go with Janine, because she is my favorite. So...or. Or report to the police. Because thats probably something I should do.

The police found the hackers! Free publicity! Wow thanks hacker guy.

Our users are really going up. This is going great.

Oh oh! I'm really liking this. I have a lot of users now. They're really liking my game. You don't even know how happy this is making me.

Oh! Oh no. An angry customer... [text] Just gonna wait this out. NO? After two hours...no! So many users, 437 have left because...jeez. sorry.

I would say computer science.

Oh one of your workers can go [text]. Ok I'm gonna send bruce because he sounds like he spends too much time watching history documentaries.

James from accounting called [text] Oh wow. That makes me feel so good about myself!

OK I'm gonna send Nancy because Janine is my fav and we uh need her handy.

Oh Bruce came back! With greatly increased maintance skill. Oh wow that is greatly increased.

Uhm...lets train the staff because why not.

Because you could fit..uh...what...no....ok. Its ok, at least we fixed it.

Two hundred...left..no stop leaving me! Thankfully we took time train our staff. Good! Good it wont happen again. I need my users.

Oh mannnn oh I really didn't get enough users.

Ok one second. *aside* So I don't need to clear the logs? Just restart, correct?

Yes, we will just append the logs.

Cool!

Ok so I'm gonna show you something at the beginning that will make the game easier for you.

Ok! I like Nancy, she is sassy. All of them are sassy.

[Start game 2]

Oh! New people. I like this guy. (Ivar)

Alright so if you go down here. And click this. Here Frieda says you can reassign any of the to development? So click here, yeah, and you can put them on development. So last time...

They were all on maintenance.

Correct, so you weren't actually making any new features.

Wooah this is crazy. I like Ivar, he looks kinda creepy and I love it. I like his creepy long hair with a bald head.

So you see how the features...yeah the progress is at 42%? Its going up because its actually being made.

Oh wow! Wow look at that...tumblr...wow.

One of your workers can go to a two day conference...no I'm not gonna send Ivar because I don't want him to creep out all the...I'm gonna send Vani.

[Feature Completed] Oh wow, so many people. They love my game! Or...whatever we are doing. I think its a game. Yeah its a game!

Oh report this to the police. The police will help.

Vani, yes, my fav! Great maintenance, wow. I'm changing you to development.

And I reached my goal!

Hackers stole some users data. Ohhh Ignore it! Phew avoided that. -- An independent security...wha---No! Maaaaan.

Its ok. Its ok.

An angry customer....I'm just gonna wait this one out. Nooooo come back! Ok. Ok.

This is intense, honestly.

One of our engineers....ok. Estaban. I'm gonna have you doing that.

Ok, train this staff. And now everyone left because they're like, "Wow. They're dumb. Don't have good taste in game."

Aghh almost there. Just did a lot of bad exposure things

[end game]

Ok so I just have a couple more questions. Did anything surprise?

The first time I didn't get the development thing. That really changed it.

Anything about the story or the characters?

I really liked it actually. Nothing that like surprised me that completely caught my attention. It all seemed pretty natural, nothing seemed out of place.

Thank you. What types of decisions did you have to make in this? And how did you, uhm, decide. How did you make those decisions?

Uhm when the hackers were on me, I had to decide what I'd let the public know, and what I didn't want to let the public know.

Mmm hmm.

So I thought that was kinda cool. I really liked how I had to choose which one went and did the jobs.

So having gone through this a couple times, how did the decisions pan out from when you let the public know to when you didn't? Did one end up being better?

See, last time I was like "oh I'll let them know, and everyone got mad." So I thought I'd just keep it a secret. But then when I was exposed, everyone was like, "why didn't you tell use that." They all got really mad and left me, which I think is what made my exposure go up. But last the didn't like that. This time they don't like it more.

Yeah. Ok I'm gonna stop this music from playing. So where do apps come from/

Uhm, computer developers and companies. A lot of them come from apple itself. Because, ya know, the apps that are already on then. Yeah, coding obviously. You can't really make a computer program witout coding.

Do you think you could get a job making an app?

I think I could, yeah! I seem to be pretty good at coding in the coding classes we have at school. We have on called B.I.T. I don't remember exactly what it stands for, but you do a lot of coding in that.

Thats cool.

I think I totally could.

How does someone get a job making apps?

I assume that after they get a degree in computer science, or I'm sure there a school that specializes in like app creation. You could go to like adobe, like the ones that made the sketchbook app, uhm, if you're looking for more artistic or graphic designee stuff. Or you could go to apple. Game companies, develop applications there.

Is there software that exists outside of game companies?

Yeah like...uhm...scheduling and planning. And like...thats the only one I can think of because I don't use them much. OH music! How could I forget that. There are a lot of music applications. Ok so the last thing, do you have any questions for me?

No.

Cool. Well then--

Let me throw in a question from left field here. What is it that made you like Janine so much?

Uhm. She was idk. From her description she seemed really on it. She seemed really cool. I liked her a lot.

And at the very beginning, the first thing you said was that you liked, uhm--

Nancy?

Yes, Nancy. Was there a reason? That was before you had openend up and read about her.

She looked really sassy. And she looked like me before I went insane. Cuz I used to have long blond hair and that was normal. It was gross. But she was really sassy so I liked her. Sassy like not really sassy but like, cool. Like she looked hip with the kids.

Yeah! Ok, I think thats all we have. Thank you!

Subject 10

Ok So your favorite subject is?

History.

Whats your favorite app?

Facebook.

Ok. Any others?

Mostly social media. Facebook, Instagram...I have this called wattpad I used all the time.

Where do the apps from?

From the app store. People make them and sell them on the app store.

What do you think those people are like?

Like they know how to program stuff. And...they know how to use the technology to build the apps to put them on the appstore for people to use.

If you had to describe the way that they look?

The way that they look? Uhm...smart? Or...I don't know. They look smart or techy I guess.

Do you think they went to college?

Most likely. Probably.

What do you think they studied?

Uhm, I'm not sure.

Thats ok! Valid answer.

[Introduces game]

>>5:30<<

[end game]

So. What surprised you in that?

Well there was like, a lot of different...ok. It was different from any video game I've played. I had to think about what I was doing before I just clicked anything. I had to figure out what this button meant before I started just doing something. I had to kind of learn as I went.

What types of decisions did you have to make?

Well I had to decide whether I just reset the password or I would train everyone on how to decide on passwords so that they wouldn't get broken into again. And then I had to decide which person was going to do the maintenance part and which person did the development part. And that probably affected...something.

Yeah when you...did you see...you saw the features page and how the percentage was going up?

Yeah.

The people working on that were the feature people, and the people on maintenance were on the exploits page, the things taking away users, the people on maintenance were getting rid of those. So how did you make those decisions.

Well I've always thought about not having weak passwords, so for the password one, I always try to make them as strong as possible so no could find them out. And for the other ones I just experimented for the first minute to figure out which was the better one.

Specifically about the one where it said someone had attacked your company and you had the option to retaliate, why did you decide to retaliate?

I guess I'm an aggressive person. I was kind of..

Was it good?

No, I probably shouldn't have. I probably should have let the police handle it instead of taking it into my hands.

Maybe. Good to know. Where do apps come from?

People like you who make them and develop them. Take a lot of time to make them.

What do those people look like?

Like you? Like normal people.

Just like me?

Like anybody!

What did you notice about the characters?

I noticed some of them had degrees from Ball State. And then they didn't look like smart people, they looked like normal people.

Do you think you could get a job making apps?

Possibly, if I thought about it and was patient with myself, then probably.

Why?

I can because I don't have to be super smart. you still have to have some knowledge about how to program and everything, but I think once I learned how to do that I would have a little bit more...uhm...chance of being more successful and making an app or a game.

So after having practiced?

Yeah!

Alright so last thing, any questions?

Nope! It was fun.

Subject 11

All right, I'm just gonna start with a few questions. First off, what is your favorite subject in school?

Hmm...probably Gym. Does it have to be like an english or math?

No, thats good. But if you had to pick an academic one?

Probably science.

Alright, whats your favorite app? Which one do you use the most.

I don't actually have my own personal device like that, but we have a family one, so...

It could be, like, whats your favorite game? If you play video games?

When I do play, probably Clash of Clans.

Alright. Where do apps come from? Like apps or games.

The app store? Or do you mean before that?

Uhm. Yes, but, if you think of the people who made them.

Well I do read who made them, if its like catch app or someone like that.

If you think about the individual people who work on them, what would you say they look like?

Like, physical appearian--appea--

Mhhmm, appearance.

Uhm.

And so you know, I don't know is a valid answer throughout this whole process.

Yeah, I don't know.

Do you think they went to college?

I would assume so to learn how to make it. But I have some friends who can program stuff who haven't been to college, so.

If they did go to college, what do you think they majored in?

Probably some sort of technology...computer science maybe.

Alright, thats all I have beforehand.

[introduces game]

Whats a press release?

Its--like contacting a news station, or I guess today using social media. Saying what happened, letting the public know what is going on.

Ah ok.

[end game]

Alright, do you want a second go on that? You figured out half way through that you can change people's task, but that really affects the game.

Yeah, I'd like to give it a try.

Alright lets start you off. So I'm not sure what happened last time, but right here are the instructions, so you can read through those.

[Start Game]

[End game]

So did anything surprise you?

Well, a lot of the video games I play aren't very realistic. This one is pretty down to earth. In like the things that happen. And up to date.

So, what types of decisions did you have to make.

Well you had to work with your customers and learn how to make them happy while also...uhm...increase your benefit and keeping away people who wanted to steal that.

How did you make those decisions?

Well I knew some of them would hurt me no matter what I did so like the best possible answers. And some of them, I really didn't know what to do, so I just guessed.

Do you remember any in particular you just guessed about?

Uhm...The one, the first problem. Where you could tell the police about it or send someone after it.

The first time you played through you chose to have someone retaliate and the second time, you reported it to the police.

Yeah, neither of those worked, I probably should have just done nothing. --- I don't really remember what happened with the police, actually.

You celebrated because they found who it was and you got users because of the publicity.

Oh! I thought that was a different...ok nevermind! I thought it was a different one. Yeah that one worked, so I went with that.

Same question from before, where do programs and apps come from?

Uhm, yeah people, groups of, like, you buy them from the app store, but people will make them on their own. Or different organisations.

Do you think you could get a job making apps?

I could but thats...thats not really...I don't know a whole lot about it. I could if I took that career path.

What is that career path? How do you get to that?

There was computer science on there and that worked both times I tried that, so probably something like that. Thers probably a lot of mathematics and, you know, how you have to know how games work or what other people did to make the games.

Yeah so how do people in general gets jobs in making software? Like do you think they went to college and studied and?

My uncle has a job in computer software but he didn't graduate from college. So I don't think you have to.

So there are multiple ways?

Yes.

Alright I think thats all...one more. What did you think about the characters? You read their bios several times.

I thought that was probably a pretty balanced team, because you had someone who, like, majored in three of the important categories, such as computer engineering. I can't remember what the one in the middle was, and then there was another one who was good at working with people and finding out what they want. Thats why I chose her to do the--oh no, I chose the engineering one to teach people how to do the password thing because he knew how to make a safe password. And then I would have chosen her to find out what people liked or stuff like that.

Alright thats all I have. Do you have any questions for me?

Not really.

Subject 12

I'm going to start off by just asking you a few questions. Whats your favorite subject?

Writing.

Alright. What is your favorite app or game? On technology.

I don't know.

Where do apps and games come from?

A creator.

So a person makes it. What...what do you think that person looks like? If you had to imagine the person who makes these things, what would you say they look like?

I don't know, I've nevers seen them.

Ok. Do you think that they went to college?

Probably.

If they did, what do you think they studied?

Computer technology.

[introduces game]

Is it just gonna move on, or?

Just click on the screen.

time passes

So every time this flashes, time stops and it has someting for you.

time passes

What is...?

Ok, if you click here, you'll see...right there, 28% on development? If you put someone's task to that, they work on completing it. That percentage will go up. Once you take care of this event, that'll start goin up again.

time passes

What do these do?

Uhm...so now time has stopped since there is something here. Click on this one. These are are things that take users, but since you have him on maintance, this one is already fixed. Now click here. These are things you are making. She is working on those and once you have that you'll

start making more users.

[end game]

Did anything surprise you?

Not really.

Ok. What types of choices did you have to make?

Uhm. Like whether or not to train staff and have them not working for a time.

Mmhmm. And how did you make that decision? How did you choose whether or not to do that and who to send?

I don't know...

Ok! That's fair. After having played, same question, where do apps come from?

The creator.

Do you think you could...when you're grown up, do you think you could get a job making software--making apps?

No.

Why not?

Because it's something that interests me so it's not something I could work very hard at.

Ok. What do you find interesting?

confused silence

Another way--what do you want to be when you grow up?

Really, only God knows what I'll be and I, I don't know.

Ok! Fair. In general, how do you think someone gets a job making apps?

You would go to college and study and...get hired or start a business.

Mmhmm. Study what?

Computer science.

Alright. Those are all the questions I have for you. Do you have any for me?

Shakes head

Subject 13

To start, I'm going to ask you a few questions. What is your favorite subject?

Uhm...writing.

Alright. What is your favorite app?

What?

What is your favorite app? App, game...so like on technology, do you have a favorite? It's ok if you don't.

You mean like a game or anything online?

It can be anything really. If your favorite happens to be the dictionary app, that's alright too!

I don't really have one.

Ok. That's fair. Where do apps come from?

Well, people have to make em.

Mmhmm. Describe those people.

Uhm, people that know computers. Computer programs.

If you had to describe what they look like? If you imagine that person in your head and you were describing what they physically look like. If you were gonna write about them?

Uhm...geeky...

Geeky?

Yeah.

Alright, do you think they went to college?

Yes.

What do you think they studied?

Computer science.

[introduces game]

Feel free to ask questions, I'll explain anything you don't understand.

What do I do?

You just click.

What do I do?

Click on the button that is flashing.

Uhm...

So if you click on him here...yeah. So you can do that for any of them. And then if you click on these buttons--

Here?

Yes. There you can decide if you want them on developing or maintaining because thats what they are working on.

And now what do I do?

Click on him again and that'll make it smaller. Then click here.

The red?

Yeah, whenever that is flashing like that, it needs your attention.

[end game]

Ok, did anything surprise you?

Not really.

Ok! There are no wrong answers to these questions. What types of decisison did you make.

Uhm whether to train the staff.

Mmhmm. How did you make that decision?

Train em.

Yeah thats what you decided. Why did you decide that?

To....secure the area more. Company more.

Alright. Where do apps come from?

Where do apps come from?

Mmmhmm.

Well...well still people have to make em still.

Do you think you could get a job making apps?

No.

Why not.

Well I guess I could but...

But?

Well I'd have to take the right school stuff.

So you could but you would have to study the right things. What would you have to do, to study in order to?

Computer engineering and computer science.

Ok! Is that something that happens only in college or can you start learning beforehand?

You can beforehand.

How does someone get a job doing that.

You have to be experienced enough to...for someone to want to hire them.

Ok. How...after playing that game, how important is it to make sure that you're doing on computers is safe?

Very.

Ok! That's all I have. Do you have any for me?

No.

Alright, then we are done! Thank you very much for participating.

Appendix H: Game Play Logs

The following are the detailed gameplay log for each subject, marked by the subject's number. When a session included more than one play through the game, the logs are provided sequentially and annotated with a sequence number; for example, 1-2 is subject 1's second play of the game.

368

1-1:

CEO is Nancy; workers are Janine, Vani, Abdullah,
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Graphic Design
edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release
Set volume to zero
Set volume to zero
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Janine
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Vani
edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users
Final users: 2603; exposure: 0.0069495

1-2:

Game started
CEO is Melissa; workers are Esteban, Ivar, Bruce,
Esteban task changed to Development
Esteban task changed to Maintenance
Esteban task changed to Development
Ivar task changed to Development
Ivar task changed to Development
Esteban task changed to Development
Expanded: Ivar
Collapsed: Ivar
Esteban task changed to Maintenance
Ivar task changed to Maintenance
Bruce task changed to Development
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Graphic Design
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Ivar
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
Esteban task changed to Development
Esteban task changed to Maintenance
edu.bsu.cybersec.core.narrative.DDOSEvent: Just Wait
Bruce task changed to Maintenance
edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users
Ivar task changed to Development
Esteban task changed to Development
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Bruce
Final users: 13112; exposure: 0.1412592

2:

Game started

CEO is Abdullah; workers are Janine, Melissa, Esteban,

Janine task changed to Development

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

Esteban task changed to Development

Melissa task changed to Development

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Janine

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Esteban

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

Final users: 26191; exposure: 0.0674723

3:

CEO is Jerry; workers are Vani, Bruce, Nancy,

Expanded: Nancy

Collapsed: Nancy

Expanded: Bruce

Expanded: Vani

Collapsed: Vani

Nancy task changed to Development

Bruce task changed to Development

Expanded: Vani

Collapsed: Vani

Expanded: Bruce

Collapsed: Bruce

Bruce task changed to Maintenance

Expanded: Nancy

Collapsed: Nancy

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Nancy

Expanded: Vani

Vani task changed to Development

Vani task changed to Maintenance

Bruce task changed to Development

Collapsed: Vani

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Vani

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

Vani task changed to Development

Bruce task changed to Maintenance

Nancy task changed to Development

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

Final users: 6725; exposure: 0.092293896

4:

CEO is Esteban; workers are Janine, Nancy, Vani,

Expanded: Janine

Collapsed: Janine

Expanded: Nancy

Collapsed: Nancy

Expanded: Vani

Collapsed: Vani

Nancy task changed to Development

Expanded: Nancy

Collapsed: Nancy

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

Expanded: Janine

Expanded: Nancy

Expanded: Vani

Collapsed: Vani

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Vani

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Graphic Design

Expanded: Janine

Expanded: Nancy

Collapsed: Nancy

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

Expanded: Janine

Expanded: Nancy

Expanded: Vani

Collapsed: Vani

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Nancy

Final users: 39247; exposure: 0.05003875

5:

CEO is Ivar; workers are Nancy, Vani, Melissa,

Nancy task changed to Development

Expanded: Nancy

Expanded: Vani

Expanded: Melissa

Collapsed: Melissa

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

Melissa task changed to Development

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Nancy

Melissa task changed to Maintenance

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

Melissa task changed to Development

Melissa task changed to Maintenance

Melissa task changed to Development

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

Expanded: Vani

Expanded: Nancy

Expanded: Melissa

Expanded: Vani

Collapsed: Vani

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Vani

Final users: 17423; exposure: 0.07671654

6:

CEO is Esteban; workers are Abdullah, Janine, Jerry,

Expanded: Janine

Collapsed: Janine

Expanded: Jerry

Collapsed: Jerry

Expanded: Abdullah

Collapsed: Abdullah

Jerry task changed to Development

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Jerry

Abdullah task changed to Maintenance

Janine task changed to Development

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

Jerry task changed to Development

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Jerry

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

Jerry task changed to Development

edu.bsu.cybersec.core.narrative.DDOSEvent: Just Wait

Final users: 25900; exposure: 0.096139066

7:

Game started

CEO is Nancy; workers are Jerry, Esteban, Janine,

Expanded: Jerry

Jerry task changed to Development

Collapsed: Jerry

Expanded: Esteban

Collapsed: Esteban

Expanded: Janine

Collapsed: Janine

Expanded: Esteban

Collapsed: Esteban

Expanded: Jerry

Collapsed: Jerry

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

Esteban task changed to Development

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Jerry

Expanded: Jerry

Collapsed: Jerry

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Engineering

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Jerry

Final users: 33994; exposure: 0.065729424

8:

CEO is Jerry; workers are Janine, Vani, Esteban,
Janine task changed to Development
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Esteban
edu.bsu.cybersec.core.narrative.DDOSEvent: Just Wait
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Esteban
Final users: 38580; exposure: 0.070904195

9-1:

Game started
CEO is Jerry; workers are Bruce, Nancy, Janine,
Expanded: Nancy
Expanded: Bruce
Expanded: Janine
Collapsed: Janine
edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users
Expanded: Janine
Collapsed: Janine
Expanded: Nancy
Collapsed: Nancy
Expanded: Bruce
Collapsed: Bruce
edu.bsu.cybersec.core.narrative.DDOSEvent: Just Wait
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Bruce
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Nancy
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
Final users: 5493; exposure: 0.012339515

9-2

CEO is Melissa; workers are Ivar, Esteban, Vani,
Expanded: Ivar
Ivar task changed to Development
Collapsed: Ivar
Vani task changed to Development
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Vani
Vani task changed to Development
edu.bsu.cybersec.core.narrative.DDOSEvent: Just Wait
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Esteban
Vani task changed to Maintenance
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
Final users: 25899; exposure: 0.18964696

10:

CEO is Jerry; workers are Melissa, Bruce, Vani,

Expanded: Melissa

Expanded: Bruce

Expanded: Vani

Expanded: Bruce

Expanded: Melissa

Expanded: Bruce

Bruce task changed to Development

Expanded: Vani

Vani task changed to Development

Collapsed: Vani

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

Expanded: Melissa

Collapsed: Melissa

Expanded: Bruce

Collapsed: Bruce

Bruce task changed to Maintenance

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Vani

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Melissa

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

Bruce task changed to Development

Final users: 21280; exposure: 0.094213806

11-1:

CEO is Nancy; workers are Esteban, Jerry, Bruce,

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

Bruce task changed to Development

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

Jerry task changed to Development

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Esteban

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Jerry

Esteban task changed to Development

Jerry task changed to Maintenance

Final users: 11928; exposure: 0.15418494

11-2

CEO is Nancy; workers are Esteban, Jerry, Bruce,

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

Bruce task changed to Development

edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release

Jerry task changed to Development

edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Esteban

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Jerry

Esteban task changed to Development

Jerry task changed to Maintenance
Final users: 11928; exposure: 0.15418494
Game started
CEO is Vani; workers are Janine, Ivar, Abdullah,
Expanded: Janine
Expanded: Ivar
Expanded: Abdullah
Collapsed: Abdullah
Abdullah task changed to Development
Expanded: Janine
Expanded: Ivar
Expanded: Abdullah
Collapsed: Abdullah
edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
Expanded: Ivar
Expanded: Janine
Expanded: Abdullah
Collapsed: Abdullah
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Janine
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science
Abdullah task changed to Development
Abdullah task changed to Maintenance
Janine task changed to Development
edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release
Expanded: Abdullah
Collapsed: Abdullah
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Abdullah
Final users: 22768; exposure: 0.096434705

12:
CEO is Abdullah; workers are Vani, Nancy, Ivar,
Nancy task changed to Development
edu.bsu.cybersec.core.narrative.DataStolenEvent: Notify our users
Nancy task changed to Maintenance
edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Vani
Nancy task changed to Development
Ivar task changed to Maintenance
edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science
Vani task changed to Development
Vani task changed to Maintenance
Ivar task changed to Development
edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Ivar
Ivar task changed to Development
edu.bsu.cybersec.core.narrative.DDOSEvent: Press Release
Set volume to zero
Set volume to zero
edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords
Final users: 31255; exposure: 0.06462003

13:

CEO is Nancy; workers are Vani, Ivar, Jerry,

Expanded: Jerry

Jerry task changed to Development

Expanded: Ivar

Ivar task changed to Development

Collapsed: Ivar

edu.bsu.cybersec.core.narrative.ChildAdviceEvent: Computer Science

edu.bsu.cybersec.core.narrative.InputSanitizationEvent: Jerry

Jerry task changed to Development

edu.bsu.cybersec.core.narrative.DDOSEvent: Just Wait

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Just change his password

edu.bsu.cybersec.core.narrative.SecurityConferenceEvent: Ivar

edu.bsu.cybersec.core.narrative.InsecurePasswordEvent: Train staff on secure passwords

Vani task changed to Development

Final users: 19108; exposure: 0.15697393